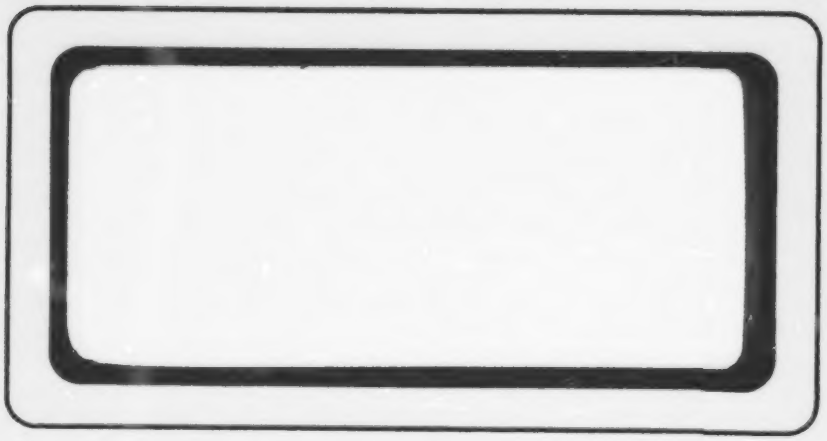

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Impact Assessment of Acid Drainage from an Abandoned Copper Mine on Mt. Washington

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ABSTRACT

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Investigations of the effects of acid mine drainage from an abandoned copper mine on Mt. Washington, Vancouver Island, included water quality sampling, measurement of flows, biological surveys and fish bioassays. The north block of the minesite was found to be the principle source of acid mine drainage. Metal concentrations were found to peak during May snowmelt and after fall rainstorms; concentrations decreased downstream with increasing dilution. Copper concentrations sufficient to have impacts on aquatic life were found from Pyrrhotite Creek downstream through the Tsolum River during the spring peak. Impacts on the fisheries resource were shown, both from acute toxicity and implied from reduced diversity of the aquatic insect community. Reclamation and abatement at the north block of the minesite is requisite to recovery of the Tsolum River below the confluence with Murex Creek.

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Impact Assessment of Acid Drainage from an Abandoned Copper Mine on Mt. Washington

1.0 INTRODUCTION

The likelihood of a water quality problem in the Tsolum River became recognized in 1984. Following a review of water quality trends in the Tsolum River, Malcolm Clark of the Waste Management Branch recommended that the Ministry of Environment conduct investigations of water quality in the Tsolum River and suspect tributaries. An initial field trip was conducted in June, 1984. Coincidently, Bill McLean, working for the Department of Fisheries and Oceans at the Quinsam Hatchery, called for a review of Tsolum River water quality, based on returns to the Headquarters Creek Hatchery; he initialized a water sampling program in Murex Creek and the Tsolum River from March to August of 1984.

Government agencies had been aware prior to 1984, of metals leaching at the Mt. Washington minesite. Explorations of the Domineer Showings date back to the 1930's. The Mt. Washington Mining Company Ltd. was formed, and mining started in 1964 (Jack Robinson, 1985). A mill, 4.5 miles (7 kilometers) from the mine was opened in December, 1964. Open pit mining continued through to the end of 1966, but the mill operated until the end of March, 1967. Both the Federal Department of Fisheries and the Provincial Pollution Control Board had investigated problems with the operation. In August, 1966, the Pollution Control Board advised the Company to apply for a discharge Permit. Esso Resources Ltd. held the mineral rights from October 1978 to July 1983. Esso Minerals Canada had been aware of metals contaminated seeps as early as 1972 (C. A. Aird, 1985). In 1979 and 1980, Esso Minerals Canada conducted metals leaching experiments in waste rock under a Letter of Approval from the Pollution Control Branch. Although data gathered at that time showed metal contamination in streams near the minesite, impacts in the Tsolum River were not known.

There is still some interest in the area. Imperial Metals Limited has leased the base minerals rights (e.g. copper) from the owner, Fording Coal Limited. Better Resources owns the rights to precious minerals and has been conducting (1986) exploration for gold.

Late in 1984, the Ministry of Environment started a review of the available historical water quality data on the Tsolum watershed, and other affected areas. The review resulted in a report entitled "A Preliminary Assessment of Acid Mine Drainage from an Abandoned Copper Mine on Mt. Washington, B.C." by Kangasniemi and Erickson (1986). This report compared historical water quality data, up to September 1984, with established water quality criteria. It

concluded that acidic mine drainage from the abandoned copper mine on Mt. Washington had periodically released sufficient copper to endanger aquatic life including fish in the Tsolum River. It indicated that both the Oyster River and Tsolum River systems were affected, but that the Tsolum River, via Pyrrhotite Creek, was the main concern. The report recommended the following:

1. a detailed survey of water quality in all drainages from the minesite;
2. a survey of water quantity, concentrating on the snowmelt period;
3. a list of parameters to test, principally heavy metals;
4. a survey of water users;
5. a biological monitoring program to assess present impact; and,
6. a program to monitor recovery after any reclamation.

As the above report was being finalized, the regional staff of the Waste Management Program, Ministry of Environment, started some physical investigations and water sampling (summer 1985). A water sampling program was implemented in the fall of 1985 which continued through the spring of 1986. The Department of Fisheries and Oceans (Hatcheries) conducted coincident water sampling of Murex Creek and the Tsolum River. In addition to this general water quality sampling, Keith Ferguson, of the Environmental Protection Service, conducted some detailed sampling of seeps at the minesite.

Although assessments of impact can be inferred from water quality data alone, it was determined that biological data was necessary to provide adequate environmental impact assessment. Consequently, the Waste Management staff sampled fish and benthic invertebrates, conducted an in-situ salmonid egg bioassay, an in-situ fish bioassay, and had bioassays done on water collected from contaminated streams.

The purpose of this report is to collect and summarize available water quality and biological information for the Tsolum River watershed. Historical water quality data for up to September 1984, available in Kangasniemi and Erickson (1986), is not included, but water quality data gathered since, up to July 1 of 1986 is included. As well as water quality data, data from bioassays and biological surveys is included. Data gathered by Federal agencies is not reported in full, but, for important parameters, is summarized. This report provides an environmental assessment of the impact of acid mine drainage on the Tsolum River.

2.0 PHYSICAL DESCRIPTION AND HYDROLOGY

The abandoned minesite is located approximately 1.5 kilometers north, and slightly northwest, of Mt. Washington (see Figure 1 and 2). There are two main routes for access, both on logging roads owned by Crown Forest. The northern route is via a road called Branch 126, which has connections to both the skihill to the west and to the Crown Forest log sorting area to the north. The south-eastern route forks off the road which goes to the Mt. Washington ski hill; it is called the Mill Road because the abandoned millsite is adjacent to this road. The mine is approximately 6 kilometers northwest from the mill site. The mine and mill operated from 1964 to 1967. Tailings from the mill were piped eastward for approximately 2.5 kilometers to a tailings pond. Since abandonment of these sites, no reclamation work has been done.

The minesite is situated at high elevation, approximately 1,310 meters (4,300 feet), on a ridge. Consequently, the uphill watershed is small, only 7 hectares, and drainage from the area flows toward both the Piggott (Oyster) and Tsolum watersheds. Two working areas are apparent, a north block comprising approximately 7.4 hectares and a south block covering about 5.7 hectares (see Figures 3 and 4). Both areas had active mining and contain dumps of waste rock, but the south block is more obviously a pit area due to exposed headwalls.

Water in the south pit area drains toward McKay Lake, from McKay Lake through McKay Creek and through Murex Creek to the Tsolum River (see Figures 2 & 3).

Water in the north block drains toward both the Tsolum and Oyster Rivers (Figure 3). A map prepared by Keith Ferguson of surface drainage and seepage patterns (Figure 5) shows the division between these drainages. Drainage zones AA, BB and CC drain to Pyrrhotite Creek, through Murex Creek to the Tsolum River. Drainage zone DD drains toward Piggott Creek and Oyster River. Seep 1 (Figure 5) includes water from a small seep which flows from the base of waste rock and from a diversion ditch which drains surface water across the uphill side of the north block. This diversion ditch was constructed by the Ministry of Environment, Water Management Program to divert clean water away from the waste rock to reduce the quantity of water generating acidic drainage. Seep 2 flows north from the dump face to Branch 126 logging road where it was sampled at Site E206514. Seeps 1 and 2 flow off the mountain along two separate streams, but join above monitoring Site E206684 near the Piggott Mainline, and flow to Piggott Creek, which enters the Oyster River. The only quantitative flow data for seeps was gathered by Keith Ferguson on June 24, 1986. On that date, the diversion ditch was carrying an estimated 5 L/s of clean water which otherwise would have drained through the waste rock and added to the 10 L/s flowing to Pyrrhotite Creek.

In the summer of 1985, the Regional Water Management Program staff (Ministry of Environment), installed a stream flow guaging station on Pyrrhotite Creek upstream of Branch 126 (0125901 on Fig. 2). This site picks up the drainage from the north pit area which drains toward the Tsolum watershed. Water Management also obtained miscellaneous flow measurements on the Tsolum River, Murex Creek and Pyrrhotite Creek at the Rossiter Main logging road.

Field notes show sufficient snow on Mt. Washington to affect vehicular access for a significant portion of the year. Typically, vehicle access to the minesite area was restricted to the months of June through September.

The Mt. Washington minesite occupies a very small portion of the Tsolum River watershed. The impact on water quality appears to be much greater than might be expected given the available dilution. To answer this problem, it was hypothesized that due to progressive snowmelt uphill, i.e. high elevations melt last, the melt of accumulated snow at the minesite would contribute a proportionately large percentage of the flow. The 1986 streamflow record for Pyrrhotite Creek at Branch 126 (Figure 10) shows increasing flows on May 7, a peak on May 19, a major peak on May 25, and lesser peaks on May 31, June 15 and 18, then down to a base flow on June 29. The streamflow records for Murex Creek at the Duncan Main and Tsolum River at Dove Creek show similar peaks, as might be expected, but not as great in relative magnitude (Figure 9). For example, the peak on May 25, 1986, Pyrrhotite Creek shows approximately a 10-fold increase, Pyrrhotite at Rossiter a 3-fold increase, and the Tsolum River at Dove Creek Road a 6-fold increase.

Figure 11 shows, for 1986, the water equivalent for the snowpack on Mt. Washington, with a maximum between April 25 and 29, then depletion by June 22. This corresponds well with flow data for Pyrrhotite Creek at Branch 126 which increases through May to the 26th then decreases through June to a base flow on the 29th. Field notes show the snowpack melted at Branch 126 at Pyrrhotite Creek but substantial runoff from snowmelt continuing from the minesite at that time. There were only patches of snow at the minesite by June 24, 1986. These observations show snowmelt from the elevation of the minesite well after the lower elevations were clear and dry. Thus, it does appear that there is a disportionately high flow from the higher elevation during the May-June period.

However, flows are not the only controlling factor. The character of metal release during the snowmelt at the minesite is also a factor controlling total metal loadings and impacts in the Tsolum River. This will be further discussed in the section on water chemistry.

The location of drainages from the tailings disposal area were also investigated. The tailings pond area, approximately 7.8 ha, is built up by impoundments on the northwest and north sides. The

tails are highest along the edges of the impoundments and dip toward a ponded area at the southwest end. The tails are orange at the surface where oxidation has occurred, but are blue-grey 30 cm below the surface. The ponded area looks natural, and is being used by beavers. The tailings pond surface drainage exits midway along the northeast side, and flows through a swamp, then down to Wolf Lake (see Fig. 2). Wolf Lake flows through Headquarters Creek to the Tsolum River. The water quality of this stream is important because Department of Fisheries and Oceans has a hatchery on Headquarters Creek.

Adjacent marsh areas to the north and west of the tailings disposal area drain toward Murex Creek; also, the mill site drains to Murex Creek.

Both McKay Lake and the lake on Pyrrhotite Creek (approx. 1 km downstream of 0125901) were examined as potential areas for waste rock disposal. McKay Lake covers approximately 6.1 ha. It has a maximum depth of 12 feet and has a wide flat outlet. Pyrrhotite Lake (non-gazetted name) has a maximum depth of 23 feet which occurs in a trough along the axis of the lake. It is about 3.2 ha in size. The principle outlet has a 1.5 m beaver dam on it. Also, Pyrrhotite Lake has a second outlet midway along the east shore which releases small flows at moderate and higher water levels. The drainage path for this second outlet was not ground-proofed, but air photos show it flowing into the divide-area between Pyrrhotite Creek and McKay Creek. Neither lake contains fish.

3.0 WATER CHEMISTRY

Ministry of Environment (Waste Management) staff began investigations in the minesite area in 1985. Of particular interest were the concentration of metals, the location of seeps and the location of priority streams leaving the mine area. A monthly water quality sampling program was implemented in the fall of 1985 at the following sites:

0125901	Pyrrhotite Creek at Branch 126 logging road
E206501	Pyrrhotite Creek at the Rossiter Mainline
E206499	Murex Creek at the Duncan Bay Mainline bridge
0127620	Tsolum River at the Farnham Road bridge
0127621	Tsolum River upstream of the Puntledge River
E206513	Tsolum River at the Duncan Bay Mainline logging road, upstream of Murex Creek
E206514	One-Twenty-Six Creek at the Ski Shack, tributary to Piggott Creek

These sites were chosen for convenience of access and because they were considered to be representative of key reaches of streams. The locations of these sites are found on Figures 1 and 2. Typically, the samples from these sites were analyzed for pH, conductivity, alkalinity, dissolved sulfate, and total and dissolved metals (aluminium, arsenic, calcium, cadmium, cobalt, chromium, copper, iron, magnesium, manganese, molybdenum, nickel, lead, vanadium, and zinc). Data for pH, conductance, calcium, dissolved sulfate, total alkalinity, and total and dissolved aluminum, copper, iron, zinc, and hardness are reported in Tables 5 to 20. A list of the summary data for total and dissolved aluminum, copper, iron, and zinc is found in Table 3.

Twenty-four (24) other sites were sampled during the investigations. Typically, only the metals packages were analyzed. Data for total aluminum, total copper, total iron, total zinc, and, where available, pH and dissolved sulphate are reported in Table 4.

Staff from the Puntledge Hatchery, Department of Fisheries and Oceans (Federal), also conducted a sampling program, at Murex Creek at the Duncan Bay Mainline bridge (WMB site E206499) and at the Tsolum River near Headquarters Creek (just upstream of WMB site 0126720) in 1985 and 1986. The parameters analyzed were cadmium (total), dissolved and extractable copper, manganese, aluminum, and iron; total lead, zinc, silicon, calcium, magnesium, hardness and sodium. The results for extractable copper are summarized on Tables 19 (1984 and 1985) and 20 (1986). Sampling was usually monthly, but was more frequent during peak flows.

Keith Ferguson of the Environmental Protection Service (Conservation and Protection, Environment Canada) conducted some detailed sampling of seeps in the vicinity of the north block in 1986. Results of his data for June 24-26, 1986, appear in Figures 5-8. Seep sampling was also conducted in August, September and October of 1986.

3.1 Results and Discussion

Acidic mine drainage is produced from the oxidation of metallic sulphide ores. Chalcopyrite, bornite, pyrite, and pyrrhotite are present at this site (Jack Robinson, 1985). The bacterium Thiobacillus ferrooxidans gets energy from oxidation of reduced sulphide compounds, and its presence enhances the production of low pH, and solubilization of metals (Scott & Bragg, 1975). Keith Ferguson confirmed the presence of Thiobacillus ferrooxidans in the north block. See Figure 8. The presence of Thiobacillus ferrooxidans at this site helps explain the low pH and substantial concentration of metals found.

From time to time, reference will be made comparing water quality data to Water Quality Criteria for Aquatic Life. The following table is from Kangasniemi and Erickson (1986):

Working Water Quality Criteria for Aquatic Life

Substance	Criteria for Aquatic Life [mg/L]	Reference
Aluminum	0.1	IJC (1977)
Arsenic	0.05	Demayo, Taylor and Reeder (1979)
Cadmium	0.0002	Demayo, Taylor and Reeder (1979)
Copper (total)	0.002	Demayo and Taylor (1981)
Iron	1.0	U.S. EPA (1976)
Lead	0.005	Demayo, Taylor and Reeder (1980)
Zinc	0.05	Taylor and Demayo (1980)

Also, water quality values may be compared with toxicity data; from bioassay data LC50 values for copper in the Tsolum River for salmonids vary between 0.037 mg/L (pink salmon) and 0.074 mg/L (rainbow trout).

Copper is the principal contaminant of concern because it is the only metal which exceeds water quality criteria for aquatic life throughout the Tsolum River below Murex Creek. It is toxic at relatively low concentrations, as reflected in the criteria of 0.002 mg/L. Furthermore, copper is released from the minesite at a considerably higher concentration than is found in background waters; for instance, mean total copper in Pyrrhotite Creek at

Branch 126 was 8.01 mg/L, but mean total copper in the Tsolum River upstream of contaminated waters was 0.004 mg/L. By comparison, mean total aluminum was 8.11 mg/L at Branch 126 and 0.147 mg/L at the background site, and mean total iron was 0.67 mg/L at Branch 126 and 0.465 at the background site. Finally, although loading calculations (later discussion) show some losses of copper by natural mechanisms, copper appears to act as a conservative element in the pH ranges observed and dilution is the principal factor resulting in reduced copper concentrations.

The highest concentrations of copper and other metals were found at the north block, in seeps at the base of the waste dumps. The highest values were: total copper - 19.5 mg/L, total aluminum - 26.5 mg/L, total iron - 8.23 mg/L, total zinc - 0.63 mg/L. Several other metals which, in typical Vancouver Island waters are not detected at high detection levels, were also measured: total arsenic - 0.013 mg/L, total cadmium - 0.0020 mg/L, total cobalt - 0.3 mg/L, total manganese - 5.43 mg/L, total molybdenum - 0.03 mg/L, total nickel - 0.15 mg/L, and total lead - 0.001 mg/L (these were maximum values, not typical ones). Accompanying the high metal concentrations were low pH (minimum 3.2), high specific conductance (770 uS/cm), high dissolved sulfate (333 mg/L), and high acidity (192 mg/L, eqivalent of $CaCO_3$ to change pH to 8.3). These figures are indicative of Acidic Mine Drainage. AMD usually can be detected on the site by staining of rocks to red or orange, or, at lesser concentrations, to dark brown. These maximum concentrations were found at site 0190323, which drains to Pyrrhotite Creek. Seeps flowing north toward Piggott Creek usually had similar chemistry to those flowing toward Pyrrhotite Creek, but the flows and, subsequently, the loadings, were much smaller (approximately one-sixth). Volume of seep flows suggests their origin is from the snowmelt.

Note: the maximum total copper concentration, 19.5 mg/L, was approximately 10,000 times the recommended copper criteria level of 0.002 mg/L.

The diversion ditch was installed in order to divert clean water away from the north block to avoid contamination with AMD. On June 24, 1986, detectable metal concentrations in the ditch were: aluminum - 0.13 mg/L, copper - 0.020 mg/L, and iron - 0.12 mg/L. These values are slightly higher than found in other background surface water and may reflect mineralization in this area. Flow was estimated as 5 L/sec. Below the waste rock dump, the estimated flow was 6.0 L/sec and the copper concentration was 0.235 mg/L (Keith Ferguson, 1986). Previously, seep 1 had similar copper levels to seep 2 (Table 4). Consequently, the diversion ditch provides additional dilution to contaminated seeps flowing toward Piggott Creek.

The south block of the minesite showed metals contamination but at much lower concentrations than in seeps flowing toward Pyrrhotite Creek. Maximum values for seeps flowing toward McKay Lake were: total aluminum - 0.07 mg/L, dissolved copper - 0.41 mg/L, total iron - 0.07 mg/L, and dissolved zinc - 0.04 mg/L. The one parameter in the south block which was greater than in any north block seep was arsenic. The total arsenic concentration in the seep noted as the "green flow" (Figure 4), was 0.210 mg/L on June 26, 1985. This is 4 times the drinking water criteria of 0.05 mg/L (B.C. Ministry of Health, 1983). This area has been posted by the Ministry of Environment: "WARNING. Water in this area may be unfit for human consumption."

Drainages were next sampled 0.5 km or more from the minesite at a similar elevation: 0125901 - Pyrrhotite Creek at Branch 126, E206514 - One-Twenty-six Creek at Branch 126 (this is downstream of seep 2), and E206500 - McKay Creek at the Mill Road. The mean total copper concentration at these sites were 8.012 mg/L, 0.177 mg/L, and 0.0155 mg/L, respectively. The maximum total copper concentrations were 12.9 mg/L, 0.400 mg/L, and 0.020 mg/L, respectively. This data shows that the principal area of concern is the portion of the north block which drains to Pyrrhotite Creek. The data for One-Twenty-six Creek shows some contamination.

As previously mentioned in the Hydrology section, seep 2 flows down the mountain independently through One-Twenty-six Creek, then rejoins the stream which started as seep 1. These combined drainages were sampled at site E206684, which is well upstream of Piggott Creek. At E206684, the mean total copper concentration was 0.009 mg/L and the maximum total copper concentration was 0.020 mg/L. This latter copper concentration is not expected to cause impacts in Piggott Creek or the Oyster River due to substantial dilution, but it is still indicative of contamination by AMD. Portions of the north block draining toward Piggott Creek should be considered in any metals abatement plan.

Copper in Pyrrhotite Creek is a problem because the loadings are so high that there is insufficient dilution downstream to reduce the concentration to safe levels. Consider the following table which shows mean and maximum total copper concentrations starting at the minesite and continuing through Pyrrhotite Creek, Murex Creek, and the Tsolum River:

Location	Site	Total Copper Mean [mg/L]	Total Copper Maximum [mg/L]
Base of Waste Rock	0190323	15.6	19.5
Pyrrhotite Ck (Br. 126)	0125901	8.01	12.9
Pyrrhotite Ck (Ts. M/L)	0125900	1.33	1.66
Pyrrhotite Ck (Ross)	E206501	0.22	0.91
Murex Ck (DBM)	E206499	0.045	0.10
Tsolum R (Farnham Rd)	0127620	0.020	0.10
Tsolum R (U/S Puntledge)	0127621	0.011	0.03

The mean values show the average concentrations for the period 1985 to July, 1986; the maximums were the maximum total copper levels during the same period. Figure 10 shows the flows and copper concentrations at Branch 126. The copper concentrations are relatively stable, varying from 3 to 12 mg/L, but the flows vary widely, from almost negligible to 0.275 m^3/s. The considerable dilution which could be expected with the substantial flow does not occur. This relatively constant copper concentration even during peak flows is one of the factors contributing to the apparent disproportionate impact from this small area. The lowest copper concentration occurred after the peak flows. Possibly, the copper exists as salts which are washed out during the peak flows. A peak copper concentration also occurs in the fall with fall rains.

The high copper concentration at the minesite and progressive dilution downstream is evidence that the minesite is the source. This is further augmented with loading data. The only time both water quality and water quantity were measured at nearly the same time was June 2 and 3, 1986. Loading calculations are as follows:

Site	Flow	Total Copper	Loading
Pyrrhotite Ck at Br 126	0.090 m^3/s	3.32 mg/L	298.8 mg/s
Pyrrhotite Ck at Rossiter	0.205	0.91	186.5
Murex Ck at DBM	1.620	0.11	178.2

This table shows that there is more than enough copper leaving the minesite area to account for all the copper arriving at Murex Creek at the Duncan Bay Mainline bridge. In fact, about one third the copper is lost between Branch 126 and the Rossiter Mainline.

The summary data (Table 3) provides additional circumstantial evidence that the minesite is the source of copper contamination. Near the minesite, at 0125901, the difference between total and dissolved analyses is small for any metal (as expected with the clear water sampled). As one progresses downstream, the concentrations for both total and dissolved copper and zinc remain similar, but the difference between total and dissolved analyses for aluminum and iron increase. This is likely because aluminum and iron occur naturally in the surrounding area and are released by erosion during rainfall; the peak concentrations for total aluminum and iron occur during high, muddy flows. In downstream sites, concentrations of aluminum and iron reflect background levels. On the other hand, copper concentrations peak in correlation to runoff from the minesite. The high copper concentrations do not fall to background levels even at downstream sites.

The limited sampling in side tributaries does not show significant concentrations of copper coming in. At site E206513, the control site and main stem Tsolum River upstream of Murex Creek, the samples generally contained less than or equal to 0.003 mg/L of copper (the sample at 0.02 mg/L is considered an error). Site E206685, McKay Creek, had a maximum concentration of dissolved copper of 0.009 mg/L; other samples had less than 0.004 mg/L. Site E206686, Murex Creek at the Rossiter Mainline (upstream of Pyrrhotite Creek) had only 2 samples, with total copper concentrations of 0.011 and 0.005 mg/L. This might indicate some contamination in Murex Creek upstream; swamps at the north end of the tailings impoundment are within the Murex Creek watershed and showed a total copper analysis of 0.14 mg/L. The old mill site is within the Murex watershed and some waste is known to have been used in the construction of some logging roads. However, if contamination to Murex Creek upstream does occur, it is not harmful, as shown by later fish and benthic invertebrate survey data.

The other location with potential problems with metals release was the tailings impoundment. Five samples were recorded for the tailings pond outlet. The pH was fairly consistent at 6.4 to 6.7. Copper concentrations varied from 0.002 to 0.06 mg/L for total copper and one dissolved copper concentration was 0.09 mg/L. A high arsenic level was 0.080 mg/L; in 1979, mercury was detected at 0.00011 mg/L; lead has been measured at 0.003 mg/L on several occasions. These values do not indicate AMD. The tailings pond outlet flows to Wolf Lake, which discharges to Headquarters Creek, the source of water for the Headquarters Creek Hatchery. DFO monitoring (Puntledge Hatchery) of Headquarters Creek in 1986 showed excellent water quality with all copper values less than 0.005 mg/L, a maximum extractable aluminum value of 0.06 mg/L, a maximum extractable iron of 0.133 mg/L, and all zinc values less than 0.002 mg/L. The tailings impoundment does not appear to be the source of a significant water quality problem at the present time, but cannot be ruled out as a potential source because the site has not been reclaimed or treated. Future erosion and oxidation might be forces which could modify the present situation.

Water quality data for site E206501, Pyrrhotite Creek at the Rossiter Mainline logging road, indicated this water was continuously toxic to fish; only one sample had less copper than the 0.037 mg/L LC50 for pink salmon. That one sample had a (total and dissolved) copper concentration of 0.021 mg/L. However, the criteria for aluminum was achieved on half the samples, and the maximum total aluminum value of 0.45 mg/L is only 4.5 times the criteria of 0.1 mg/L. The water quality was always better than the criteria for iron and zinc.

Water quality data for site E206499, Murex Creek at the Duncan Bay Mainline, is interesting in that the maximum and mean values for aluminum and iron is greater than for E206501 upstream. However, inspection of the data sets shows one sample taken at this site on

October 21, 1985, a date for which no sample was taken at E206501. Field notes for that date show that the streams were high and muddy from ongoing rain. The difference between total and dissolved aluminum, 1.67 mg/L and 0.20 mg/L, respectively, show that this was an unusual sample. So, excluding that sample taken on October 21, 1985, the data for aluminum, iron and zinc always exceeded (were less than) their respective water quality criteria. On the other hand, the copper concentrations were always greater than the criteria, with only three samples less than 0.020 mg/L. From May 13, 1986 through to June 24, 1986, the copper (dissolved) concentrations were greater than the copper LC50 for pink salmon (0.037 mg/L) and were usually greater than the higher steelhead LC50 of 0.07 mg/L. Federal data showed similar results for the same time period in both 1985 and 1986. Note that during the in-situ bioassay at this site (May 28 to June 9, 1986) that there was 100% mortality of both coho salmon and rainbow trout. (In August, 1986, when fish were observed at E206499, the total copper concentration was 0.012 mg/L.) Figure 12 shows combined Ministry of Environment and Department of Fisheries and Oceans Hatchery Data for total copper at E206499; the spring peak concentrations are obvious.

The water quality for 0127620, the Tsolum River at Farnham Road, showed that water quality criteria for aluminum, iron, and zinc were always met (except for the October 21, 1985 sample). However, this site frequently had elevated copper levels. Concentrations greater than 0.037 mg/L, the pink salmon LC50, were seen in both the spring and the fall, although the maximum concentration and the most enduring high concentrations were found in the spring. The maximum total copper concentration occurred on May 13, 1986, at 0.10 mg/L. Note that the dissolved copper concentrations varied between 0.020 and 0.040 mg/L during the in-situ bioassay, May 28 to June 9, in which 50% of the test fish died. (Federal data for the Tsolum River upstream of Headquarters Creek, and upstream of this site, had an extractable copper concentration of 0.055 mg/L on May 30 and 0.045 mg/L on June 2.) This section of stream has a reduced capability to raise fish that must rear for a year in the stream, and might not be able to support fish that spawn in the fall - there might even be impacts on fish that must migrate through this section of stream.

At site 0127621, the Tsolum River upstream of the Puntledge River, the concentrations of aluminum, iron, and zinc were always less than water quality criteria. The criteria for copper was sometimes met or exceeded. On the other hand, copper concentrations equal to or greater than 0.020 mg/L occurred in both spring and fall. The maximum value occurred in the spring, May 21, and 27, 1986, at 0.030 mg/L for total copper, and 0.020 mg/L for dissolved copper. These are the same concentrations within which some mortality occurred in the bioassay at 0127620. Also, the extractable copper concentration for June 16, 1986, was 0.058 mg/L (Puntledge Hatchery data) which is well within the LC50 range for rainbow trout.

It can be concluded that during the peak concentrations of copper in the spring, there could be impacts on fish throughout the Tsolum River below Murex Creek.

This review of water quality data has shown the importance of using comparable data sets when comparing data between different sites, especially to use same-date information. As noted, only one unusual number can bias summary data calculations such as averages and maximums.

All extractions of Tsolum River water for drinking and irrigation purposes occur below the confluence of the Tsolum River with Murex Creek. The water in this section of the Tsolum River always meets the minimum criteria for these uses and, thus, can be considered safe for drinking and irrigation.

No water quality objective has been set for the Tsolum River. As yet, there is not sufficient data. The "normal" total copper concentration in the background Tsolum River site (E206513) was 0.003 mg/L and the calculated mean (which included a couple of suspect numbers) was 0.004. There appears to be some periodic contamination in the upstream Murex Creek, which drains a large portion of the Mt. Washington area; a peak value of 0.011 mg/L total copper has been observed. Some copper release from mineralization might be normal, for instance, copper concentrations in the diversion ditch were 0.020 mg/L. Also, historical EQUIS data for the Oyster River, up to 1983, give an arithmetic mean for total copper of 0.00468 mg/L. Sigma (1983) recommends a dissolved copper Maximum Acceptable Toxicant Concentration of 0.002 mg/L for water with hardness of 10 mg/L, which applies to the Tsolum River. However, this MATC was derived using an arbitrary application factor. The Sigma (1983) discussion concludes with a reference to a report which suggests an MATC for dissolved copper of 0.005 mg/L for coastal hatcheries. We recommend a water quality objective for the Tsolum River of 0.005 mg/L for total copper in order to protect fish.

4.0 BIOLOGICAL DATA

Impacts on aquatic communities may be the first indicator of problems with water quality. Even the most short term water quality toxicity problem may have an impact on aquatic life whose life cycle is spent largely or even entirely in freshwater.

Post-impact assessments must depend on pre-impact inventories, or knowledge of adjacent non-impacted sites or sites upstream of the impacted zone. The Tsolum River supports runs of pink salmon (Oncorhynchus gorbuscha), chum salmon (O. keta), coho salmon (O. kisutch), steelhead (Salmo gairdneri) and cutthroat trout (S. clarki). Pink salmon and chum salmon return as adults to the river to spawn. Eggs incubate in the river gravel over winter. The fry emerge and migrate to the sea in April and May. Coho salmon also spawn in the fall, and fry emerge in the spring, but the fry live for one year in freshwater before migrating to the salt water. Steelhead and cutthroat trout spawn in winter and spring and their fry also rear for at least one year in streams. In addition to anadromous life cycles, rainbow trout (steelhead) and cutthroat trout have resident populations which spend all their time in freshwater; usually they inhabit reaches upstream of barriers to anadromous fish. All anadromous fish will spend part of their life cycle within the impacted zone of the Tsolum River.

There is very little information on aquatic invertebrates in the Tsolum system. From data available for similar systems, endemic aquatic insect families would be represented in the Orders: Coleoptera, Collembola, Diptera, Ephemeroptera, Plecoptera, and Trichoptera. In other words, there should be a relatively diverse community of aquatic insects.

In order to provide some assessments of impacts to aquatic communities, some inventory work was conducted for fish and benthic invertebrates. In addition, some bioassay work was done in order to assess the effect of water quality on fish.

4.1 Biological Inventory Results

4.1.01 On May 10, 1979, and June 27, 1979, fishing by electroshocking by Ministry of Environment, Fisheries Section (Rick Axford), in Murex Creek upstream of the Duncan Mainline (and below Rossiter M/L) produced no fish.

4.1.02 September 10, 1984 - Murex Creek upstream of the Rossiter Mainline was fished by electroshocking by Ministry of Environment, Fisheries Section (Clough and Lough). Seven resident trout were captured (cutthroat?), sized from 40 mm to 185 mm. No coho were found.

4.1.03 On May 23 to 30, 1985, Department of Fisheries and Oceans hatchery staff put Gee minnow traps in Murex Creek at the Duncan Bay Mainline, 3 traps for three days and 2 traps for one day. No fish were captured. They reported 3 fish that looked like trout were sited on one occurrence. The creek was dry in August at the bridge.

4.1.04 On June 6, 1985, Chris Hillier (Fish Culturist from Puntledge Hatchery) swam Tsolum River above and below Murex Creek, plus Murex Creek below the logging road. No fish were seen in Murex Creek or Tsolum River 100 m below confluence. Many coho (fry and smolts) were observed in Tsolum River above the confluence.

4.1.05 On June 26, 1985, Lloyd Erickson (Ministry of Environment) walked Murex Creek from Duncan Bay Mainline to Tsolum River confluence. No fish were observed. The gradient was low; his assessment was that the creek should have held at least coho fry.

4.1.06 On July 3, 1986, electroshocking by Ministry of Environment, Rick Axford of the Fisheries Section, Lloyd Erickson and John Deniseger of the Waste Management Program, captured 13 rainbow trout in Murex Creek upstream of the Rossiter M/L (see Figure 13). No fish were caught in McKay Creek at Rossiter or Pyrrhotite Creek at the Rossiter Mainline. Coho fry were observed at: 1) Tsolum River at Duncan Bay M/L, 2) Tsolum River at Farnham Road, and 3) Constitution Creek swamp. Lack of fish at McKay Creek was likely due to the gradient being too steep. The section of Pyrrhotite Creek had good gradient and habitat, although it is upstream of the anadromous reach, and could be expected to hold resident fish.

4.1.07 Benthic macroinvertebrates were collected on July 3, 1986, using both a surber sampler and a dip net (see Figure 14). Results were as follows:

Murex Creek at Rossiter M/L (upstream of Pyrrhotite Creek)
- Order Trichoptera - 2 families
- Order Coleoptera - 1 family
- Order Ephemeroptera - 3 families
- Order Plecoptera - 1 family
- Class Turbellaria - 1 family
- Order Diptera - 3 families

McKay Creek at Rossiter M/L (upstream of Pyrrhotite Creek)
- Order Diptera - 1 family
- Order Trichoptera - 1 family
- Order Ephemeroptera - 3 families
- Order Plecoptera - 1 family
- Order Collembola - 1 family

Pyrrhotite Creek at Rossiter M/L
- No benthic organisms found

Murex Creek at Duncan Bay Mainline
- Order Trichoptera - 2 families
- Various types of green algae observed

Tsolum at Farnham Road
- Order Trichoptera - 2 families
- Order Diptera - 1 family

4.2 Bioassay Results

4.2.01 January 10, 1985 - data reported by Mike Roch for bioassays conducted at the Puntledge Hatchery using artificial concentrations of copper, provided the following for steelhead and pink salmon:

Species (stage or weight)	Source of Water (type of bioassay)	Hardness	LC 50 [ug/L Cu total] (95% confidence interval)
Salmo gairdneri (3 g)	Tsolum (static)	12 mg/L	72 (62-84)* [96 hours]
Oncorhynchus gorbuscha (100 degree days)	Tsolum	12 mg/L	71 (36-142) [168 hours]

*Concentrations were not measured; LC50 is based on nominal concentrations.
Steelhead bioassays were done November 26 - December 3 and pink alevin bioassays, December 21 - 27.

4.2.02 Similar bioassays on January 30, 1985:

The LC50's and confidence limits for pink salmon alevins (200 degree days) were as follows:

Species (stage or weight)	(type of bioassay)	Hardness	168 H LC50 [ug/L Cu total] (95% confidence) interval)
Oncorhynchus gorbuscha (200 degree days after hatch)	Murex (static)	11 mg/L	54 (46-64)
	Tsolum (static)	15 mg/L	37 (29-47)

4.2.03 Similar Bioassay reported May 29, 1985:

The results are of bioassays done with coho swim-up fry April 10 - 17, 1985:

Source of water	Temperature	Hardness	168 H LC50 [ug/L Cu] (95% C.I.)
Puntledge (flow-through)	7.7 - 8.4	17 mg/L	34 (28 - 42)
Puntledge (static)	7.8 - 9.0	17 mg/L	32 (24 - 43)
Tsolum (static)	7.3 - 9.0	10 mg/L	58 (50 -67)
Murex (static)	7.7 - 9.0	9 mg/L	54 (44 - 66)

4.2.04 On April 16, 1986, water was collected at E206501 (Pyrrhotite Creek at the Rossiter Mainline) and sent to the Environmental Lab for analysis and bioassay. The chemical analysis was: pH = 7.0 pH units, conductance = 17 uS/cm, tot. hardness = 10.1 mg/L, dis. sulfate = 2.2 mg/L; tot. aluminum = 0.15 mg/L, tot. copper = 0.07 mg/L, tot. iron = 0.04 mg/L, tot. zinc < MDC. A static bioassay was conducted on April 22, 1986 using rainbow trout. The 96 hour LT50 was 100% concentration. Two fish died in the test solution, none in the controls. The sample was slightly toxic.

4.2.05 On April 22, 1986, water samples were taken at 0125901 (Pyrrhotite Creek at Branch 126) and sent to the Environmental Lab for analysis and a bioassay. Chemical analysis had the following results: pH = 3.8 pH units, conductance = 343 uS/cm, hardness = 82.8 mg/L, dis. sulfate = 154 mg/L, tot. aluminum = 9.68 mg/L, tot. copper = 9.86 mg/L, tot. iron = 1.29 mg/L, tot. zinc = 0.27 mg/L. A static bioassay using rainbow trout resulted in a 96 hour LC50 of 0.5% concentration. There were no mortalities in the control.

4.2.06 On May 13, 1986, eyed steelhead eggs from the Robertson Creek Hatchery, were deployed in modified Whitlock - Viebert boxes at 5 sites: E206501, E206685, E206686, E206499, and 0127620 (see Figure 15). The eggs were placed in the gravel for a continuous in-situ bioassay, and were checked weekly for egg mortality and removal of dead eggs. The alevins (the eggs had mostly hatched by the end of the first week) were removed on June 3, 1986.

Results were as follows:

Site	Mortality Total	Total copper concentration (mg/L) May 13	May 21	May 27	June 3
E206501 (Pyrrhotite Cr.)	100%	0.17	0.58	0.22	0.91
E206499 (Murex Cr. d/s)	81%	0.05	0.10	0.10	0.11
0127620 (Tsolum River)	16%	0.10	0.03	0.04	0.03
E206685 (McKay Creek)	12%	0.003	0.002	0.009	0.02
E206686 (Murex Cr. u/s)	12%	0.011	0.005	--	--

The 100% mortality at Pyrrhotite Creek was evident at the first inspection; mortality took less than 8 days.

4.2.07 On May 13, 1986, water was collected from E206501 (Pyrrhotite Creek at Rossiter Mainline) and sent to the Environmental Lab for analysis and bioassay. Analysis results were: tot. hardness = 8.6 mg/L, tot. aluminum = 0.08 mg/L, tot. copper = 0.17 mg/L, tot. iron = 0.05 mg/L and tot. zinc = 0.02 mg/L. A continuous flow-through bioassay using steelhead eyed-eggs was set up to compare with the in-situ test. On March 21, 1986 additional water was taken from E206501, this water was added to the bioassay at day 7, and analysis of the combined water provided the following results: tot. hardness = 9.3 mg/L, tot. aluminum = 0.13 mg/L, tot. copper = 0.19 mg/L, tot. iron = 0.03 mg/L, and tot. zinc = 0.04 mg/L.

The results of the bioassay are in the following table:

Source	Total Mortality Day 1	Day 5	Day 8	Day 11	Day 12
Pyrrhotite Creek	0%	24%	53%	87%	90%
Control	0%	0%	0%	0%	0%

The estimated LT50 was 8 days (e.g.: time to which 50% died)

4.2.08 Water collected from E206501 on May 21, 1986, was sent to the Environmental Lab for Chemical analysis and bioassays. The analysis results were: pH = 5.8 pH units, conductance = 35 uS/cm, tot. hardness = 11.6 mg/L, dis. sulfate = 11.6 mg/L, tot. aluminum = 0.42 mg/L, tot. copper = 0.58 mg/L, and tot. zinc = 0.02 mg/L. Two bioassays were run: a) a static steelhead alevin bioassay (with aeration). The 96 hour LC50 was 8.8% concentration. b) a static bioassay using underyearling rainbow trout had a 96-hour LC50 of 17%. Also the LT50 with 100% concentration was greater than 5 hours and less than 22 hours.

4.2.09 Water collected from 0127620 (Tsolum River at Farnham Road) on May 28, 1986, and was sent to the Environmental Lab for chemical analysis and bioassay. The chemical results were: pH = 7.0 pH units, conductance= 24 uS/cm, total hardness = 10.6 mg/L, dis. sulfate = 2.9 mg/L, tot. aluminum = 0.21 mg/L, tot. copper = 0.04 mg/L, tot. iron = 0.23 mg/L, and tot. zinc < MDC. A static bioassay with underyearling rainbow trout was run with an LC50 = 100%. There were no mortalities.

4.2.10 On May 28, 1986, an in-situ bioassay was implemented using rainbow trout and coho underyearlings (see Figure 16). Torpedo tubes and live cages were used to contain the fish at the following sites E206513 (Tsolum River upstream of Murex Creek), E206499 (Murex Creek at Duncan Bay Mainline), Tsolum River approximately 1 km downstream of Murex Creek, and 0127620 (Tsolum river at Farnham Road). The test ran until June 9, 1986 with the following results:

	0127620 Tsolum R. at Farnham Road	Tsolum R. 1 km below Murex Cr.	E206499 Murex Cr. at Duncan Bay Mainline	E206513 Tsolum R. above Murex Cr.
May 28/86 (day 0)				
Live Coho	15	15	10	9
Live Rainbow	15	15	10	10
June 3/86 (day 6)				
Live Coho	11	7	0	9
Live Rainbow	10	5	1	10
Dead Coho	4 (27%)	8 (53%)	10 (100%)	0
Dead Rainbow	5 (33%)	10 (67%)	9 (90%)	0
Total Dead	9 (30%)	18 (60%)	19 (95%)	0
June 6/86 (day 9)				
Live Coho	9	5	0	9
Live Rainbow	6	3	0	10
Dead Coho	2 (40%)	2 (67%)	N/A	0
Dead Rainbow	4 (60%)	2 (80%)	1 (100%)	0
Total Dead	15 (50%)	22 (73%)	20 (100%)	0
June 9/86 (day 12)				
Live Coho	9	4	--	9
Live Rainbow	6	2	--	10
Dead Coho	0 (40%)	1 (73%)	--	0
Dead Rainbow	0 (60%)	1 (87%)	--	0
Total Dead	15 (50%)	24 (80%)	--	0

A comparison with chemical data shows the following:

Site	Mortality	Total copper (mg/L)		
		May 27	June 3	June 9
E206499	100%	0.10	0.11	0.06
Tsolum below*	80%	0.04	0.07	0.04
0127620	50%	0.04	0.03	0.02
E206513	0%	0.001	0.003	0.003

*Tsolum River 1 km below the confluence with Murex Creek.

4.3 Discussion

The distribution of fish and aquatic organisms supports observations of copper toxicity originating in Pyrrhotite Creek and flowing through Murex Creek and the Tsolum River. Pyrrhotite Creek did not contain any aquatic invertebrates or fish. Murex Creek below Pyrrhotite Creek did not contain fish during the months of May, June, or July, that is, during the period of maximum copper concentrations. Fish were observed in Murex Creek at the Duncan Bay Mainline in August 1985, and likely came downstream from the non-impacted Murex Creek. Some fish were observed in the Tsolum River downstream and unrecorded observations suggested more salmonids were present in August than in June. The invertebrate community in Murex Creek at the Duncan Bay Mainline contained only Trichopterans. This was indicative of toxicity because at least five orders of insects could be expected on the basis of invertebrate sampling in the uncontaminated reach of Murex Creek. Tsolum River at Farnham Road similarly had an impacted invertebrate community, with only two orders of insects, Trichopterans as at Murex Creek at the Duncan Mainline and Dipterans. The increase in insects suggests a slight improvement in water quality, but there was not sufficient sampling to prove this.

On the other hand, streams out of the contaminated pathway did contain healthy populations of fish and aquatic invertebrates. Murex Creek upstream of Pyrrhotite Creek contained a normal community of aquatic insects and contained fish. McKay Creek contained diverse aquatic insects. The lack of fish in McKay Creek was attributed to the extreme steepness in the reach sampled; additional sampling upstream might show some fish. The Tsolum River upstream of Murex Creek contained a healthy population of coho fry, as did Constitution Creek. It was quite clear that fish away from the contaminated stream were abundant and healthy. Murex Creek and the Tsolum River should be capable of similar productivity.

From available data, it is not clear when toxicity started to impact fish populations in the Tsolum River. The earliest evidence on record was for 1979 when electroshocking by Ministry of Environment found no fish in Murex Creek at the Duncan Bay Mainline. This sampling pre-dated the leaching experiments of Esso Minerals.

Department of Fisheries and Oceans' escapement estimates for the Tsolum River show a declining pink salmon population since 1951 and 1952, but usually with 5,000 to 10,000 until 1981; in 1982, only 50 to 200 pinks were estimated in the return; in 1983 only 1,200 and in 1984 no pink salmon were observed (W. E. McLean, 1975). The escapement records for the Tsolum River correlate well with escapement for the Puntledge River, so that the possibility exists that events in the ocean (fishing) impacted the runs. However, there is some concern that copper toxicity from the Tsolum River flowing into the Courtenay River may have affected the ability of pink salmon from the Tsolum and Puntledge Rivers to acclimatize to saltwater. This is a definite possibility since peaks of copper contamination in April and May could coincide with seaward migration of pink salmon fry.

The timing of copper peaks will likely vary from year to year according to variable weather patterns. Adult salmon returning to rivers in the fall tend to run upstream following increases in flow caused by fall rainstorms. These same rainstorms also release more metals from the minesite. Copper toxicity could occur, depending on the availability of dilution in streams at lower elevation. After the first weeks of November, however, precipitation on Mt. Washington falls principally as snow. Copper concentrations appear to stay within the non-toxic range until the spring snowmelt. If spring snowmelt occurs early enough (April) and there is insufficient dilution in low elevation streams, there could be impacts on all species of migrating salmon fry and smolts of both salmon and trout. The variable timing of weather, copper release from the minesite, and migrations of salmonids makes the use of escapement records a poor tool to show impacts on fish populations.

Bioassays were run on various species of salmonids, and with different age groups in water from Pyrrhotite Creek, Murex Creek and the Tsolum River. The following data are related to copper concentrations but potential effects of the other metals should be recognized. The mean 96 hour LC50 for rainbow trout was 0.066 mg/L of total copper, with a minimum LC50 of 0.046 mg/L and a maximum of LC50 of 0.098 mg/L. Coho fry had a mean 168 hour LC50 of 56 mg/L copper. Pink salmon had a mean 168 hour LC50 of 0.054 mg/L total copper with a minimum 168 hour LC50 of 0.037 mg/L and a maximum of 71 mg/L. The range for the 95% confidence limits were 0.029-0.142 mg/L, which is a substantial variability.

There was insufficient information to determine the most sensitive stage in fish life cycles to copper toxicity.

Bioassays run on Tsolum watershed water containing copper within the LC50 ranges showed continuing toxicity past the 96 hour or 168 hour standard toxicity test periods; test runs up to 12 days duration continued showing toxicity. This indicates that static 96 hour or 168 hour bioassay tests for Tsolum watershed waters underestimate toxicity to salmonids.

Static bioassays appeared to be less sensitive than flow-through bioassays. This confirms a commonly held generalization.

There was 50% mortality at the Farnham Road site during the in-situ fish bioassay, during the first 9 days. Ministry of Environment and Parks data showed total copper levels varying between 0.040 mg/L and 0.030 mg/L during that time. Those values were slightly lower than values derived from static bioassays, but, nevertheless, are quite close. Mortalities did not occur between day 9 and day 12 when copper levels varied from 0.03 mg/L to 0.020 mg/L.

A copper concentration of 0.030 mg/L has been observed at the lowest sampling site in the Tsolum River at some times in the year; it is anticipated that impacts to fish occur throughout the mainstem Tsolum River when this happens.

5.0 CONCLUSIONS

Acid Mine Drainage, enhanced by bacterial action, is being generated at the abandoned Mt. Washington minesite. The north block of the minesite has been identified as the source of copper contamination of the Tsolum River. Abatement of copper release from the north block is a necessary prerequisite to recovery of the Tsolum River for production of salmonids.

During the spring snowmelt, copper loadings are sufficiently high to cause some mortality to salmonids throughout the affected portion of Murex Creek and the Tsolum River. Peaks in copper loading may also occur following fall rainstorms. Salmonids with short freshwater residence time (adult spawning, to egg to fry, to fry migration to sea) such as chum and pink salmon might escape the peak copper loadings, but species with life cycles dependent on freshwater for one whole year, such as coho, steelhead, and cutthroat trout, will definitely incur impacts to their populations. Impacts on populations of aquatic insects throughout the affected streams could reduce rearing capability for fish. Chronic effects on all salmonids at the copper concentrations observed are likely, but were not documented.

The area of the minesite causing the problem in the Tsolum River is very small in proportion to the whole Tsolum River watershed. This disproportionate impact is the result of a number of factors. First, since the minesite is at high elevation, snowmelt is largely delayed relative to lower elevations, then occurs relatively rapidly at a time (May-June) when there is usually little rainfall and, thus, little dilution in the main river. Therefore, the minesite may contribute a disproportionate quantity of water to the system. Secondly, the concentrations of copper leaving the minesite are relatively stable (i.e.: is not significantly diluted by snowmelt). Thus, as flows from snowmelt increase, so does the loading. Also, the concentration of copper released is very high in comparison to levels in background water. Thirdly, copper acts as a conservative element in this system, which means that there are very few mechanisms which remove copper from the receiving water. Most of the copper leaving the minesite flows through the system. Finally, copper is very toxic to fish. Copper concentrations greater than 0.030 mg/L may cause some mortality; concentrations greater than 0.010 mg/L may cause chronic effects (Sigma, 1983).

An objective of 0.005 mg/L total copper in the Tsolum River is recommended to protect fish.

A portion of the minesite (where AMD occurs) drains toward Piggott Creek, a tributary to the Oyster River. The loadings are small, and there is sufficient dilution available that impacts to the Piggott or Oyster system are not anticipated. However, reclamation work on the north block of the minesite should include areas draining toward Piggott Creek.

The southern block of the minesite flows toward McKay Lake and McKay Creek. Initial metal concentrations are much lower than from the north block, there is significant dilution, and concentrations in the lower McKay Creek do not appear sufficient to impact aquatic life. McKay Creek flows to Murex Creek.

There may be some contamination to Murex Creek (upstream of the contaminated tributary, Pyrrhotite Creek) from the mill site and from an area adjacent to the tailings impoundment. However, fish and aquatic invertebrates were found in this section of Murex Creek, indicating no toxic impacts.

There is some minor metals contamination from the tailings impoundment. Drainage from the tailings pond flows to Wolf Lake and Headquarters Creek. Water quality in Headquarters Creek is excellent. Reclamation of the tailings area is recommended in order to assure no problems in the long term.

6.0 RECOMMENDATIONS

1. Copper loadings in Pyrrhotite Creek need to be significantly reduced in order to protect fish in the Tsolum River. Reclamation in the north block of the Mt. Washington minesite is required to abate Acid Mine Drainage and to manage water flowing toward Pyrrhotite Creek. Areas within the Piggott Creek watershed should also be reclaimed.

2. The total copper concentrations in Murex Creek and the Tsolum should never exceed 0.005 mg/L. However, more monitoring of background water quality is needed in order to determine whether this is a reasonable objective. A lower objective is desirable.

3. There should be more same-day sampling of water quality with coincident water quantity measurement through Pyrrhotite Creek, Murex Creek and the Tsolum to calculate copper loadings and to gain understanding of the water chemistry involved and to predict the level of treatment needed.

4. Monitoring of water quality in all drainages leaving the minesite should continue in order to improve knowledge of the range of concentration of metals, and to investigate the variability of those concentrations under the changing influences of weather. This would be useful in respect to abatement of copper and also is necessary to determine the safety of other uses of the water by people visiting the area (note the high arsenic levels).

5. Additional biological studies are required before and after reclamation in order to show recovery in the Tsolum River and potential for salmonid enchancement.

6. The abandoned tailings impoundment should be reclaimed in order to protect downstream fisheries. In this respect, a dam at the outlet, replacing the existing beaver dam, would maintain the existing pond and prevent generation of acid leaching in the tailings.

7.0 BIBLIOGRAPHY

1. Aird, C. A., 1985. Esso Minerals Canada, Personal Communication.

2. Demayo, A., M. C. Taylor, 1981. Copper. In: Guidelines for Surface Water Quality, Vol. 1, Inorganic Chemical Substances. Inland Waters Directorate, Environment Canada, Ottawa. 55 pp.

3. Demayo, A., M. C. Taylor and Reeder, 1979. Arsenic. In: Guidelines for Surface Water Quality, Vol. 1, Inorganic Chemical Substances. Inland Waters Directorate, Environment Canada, Ottawa. 13 pp.

4. Demayo, A., M. C. Taylor and S. W. Reeder, 1980. Lead. In: Guidelines for Surface Water Quality, Vol. 1, Inorganic Chemical Substances. Inland Waters Directorate, Environment Canada, Ottawa. 36 pp.

5. Ferguson, K., 1986. Report on Seep Survey on June 24-26, 1986. Conservation and Protection, Environmental Protection, Environment Canada.

6. International Joint Commission, 1977. New and Revised Specific Water Quality Objectives. Vol. II. Great Lakes Water Quality Board Report.

7. Kangasniemi and Erickson, 1986. A Preliminary Assessment of Acid Mine Drainage from an Abandoned Copper Mine on Mt. Washington, B.C. B.C. Ministry of Environment.

8. McLean, W. E., 1975. Memo from W. E. McLean to Brian Pearce dated May 27, 1975 re: D.F.O. Fish Culture Activities on Tsolum River.

9. McLean, W. E., 1986. Puntledge Hatchery Water Sampling Results. Puntledge Hatchery. Department of Fisheries and Oceans.

10. Reeder, S. W., A. Demayo and M. C. Taylor, 1979. Cadmium. In: Guidelines for Surface Water Quality, Vol. 1. Inorganic Chemical Substances. Inland Waters Directorate, Environment Canada, Ottawa. 19 pp.

11. Robinson, Jack, 1985. History of the Domineer Showings and the Mt. Washington Mine. Memo to G. E. Oldham.

12. Roch, M., 1985. January 10th and 30th letters to Dr. W. E. McLean, University of Victoria, Victoria, B.C.

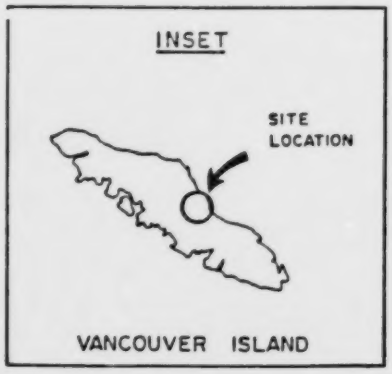
13. Scott, J. S. and K. Bragg, Eds., 1975. Mine and Mill Waste Water Treatment, Report No. EPS 3-WP-75-5, Environmental Protection Service, Environment Canada.

14. Sigma, 1983. Summary of Water Quality Criteria for Salmonid Hatcheries. Prepared for Dept. of Fisheries and Oceans by Sigma Environmental Consultants Ltd. 163 pp.

15. Taylor, M. D., A. Demayo, 1980. Zinc. Guidelines for Surface Water Quality, Vol. 1. Inorganic Chemical Substances. Inland Waters Directorate, Environment Canada, Ottawa. 52 pp.

16. van Aggelen, G. C., 1986. Bioassay Report on Effects of Acid Mine Drainage on Eyed Steelhead eggs. B.C. Ministry of Environment Aquatic Toxicity Lab.

FIGURE 1 TSOLUM & OYSTER DRAINAGE AND SAMPLE LOCATIONS



NOTE: Murex, McKay and Pyrrhotite Creeks sample sites are shown on figure 2.

FIGURE 2 MUREX CREEK DRAINAGE AND SAMPLE LOCATIONS

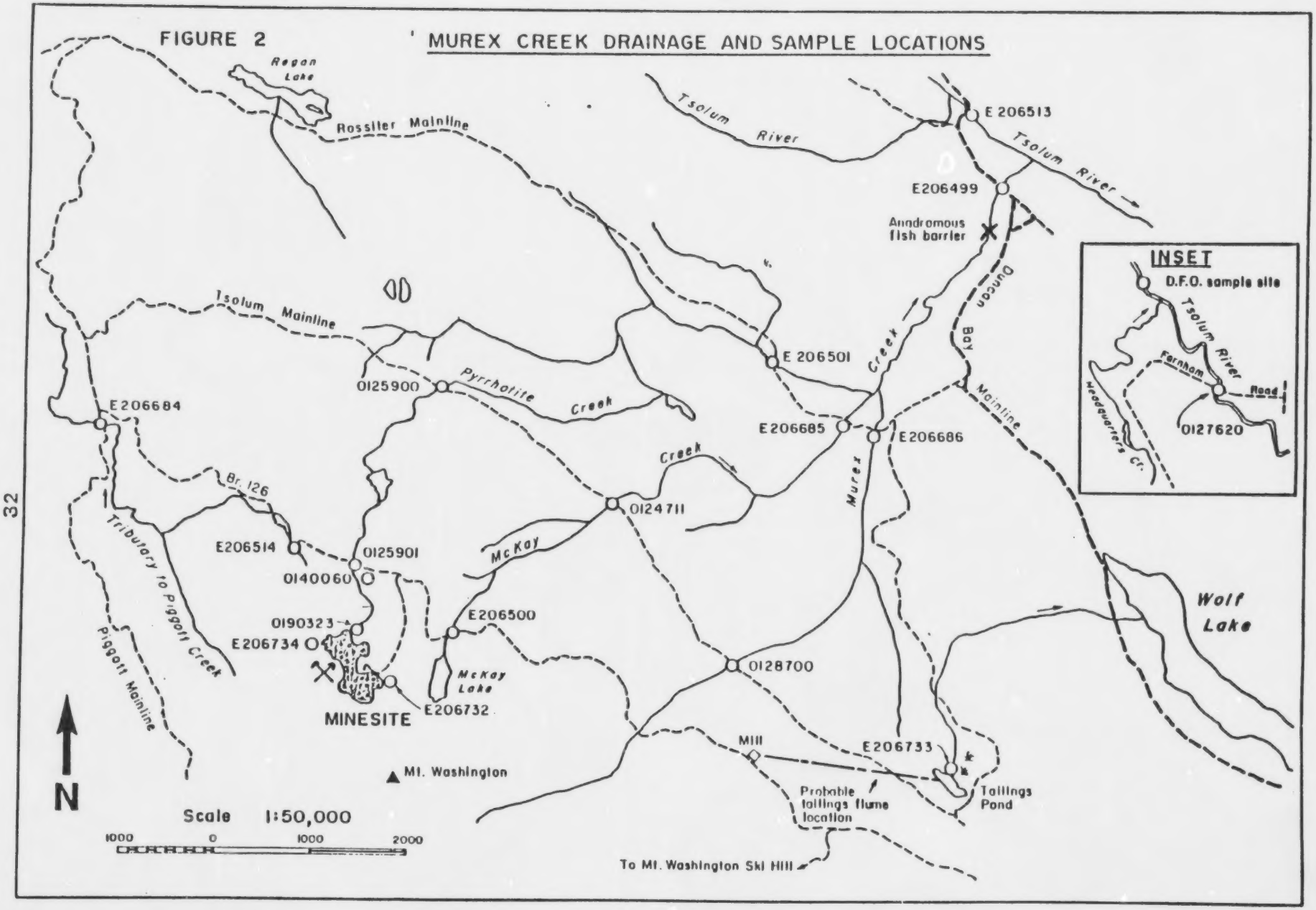


FIGURE 3 DRAINAGES LEAVING THE MT. WASHINGTON MINESITE

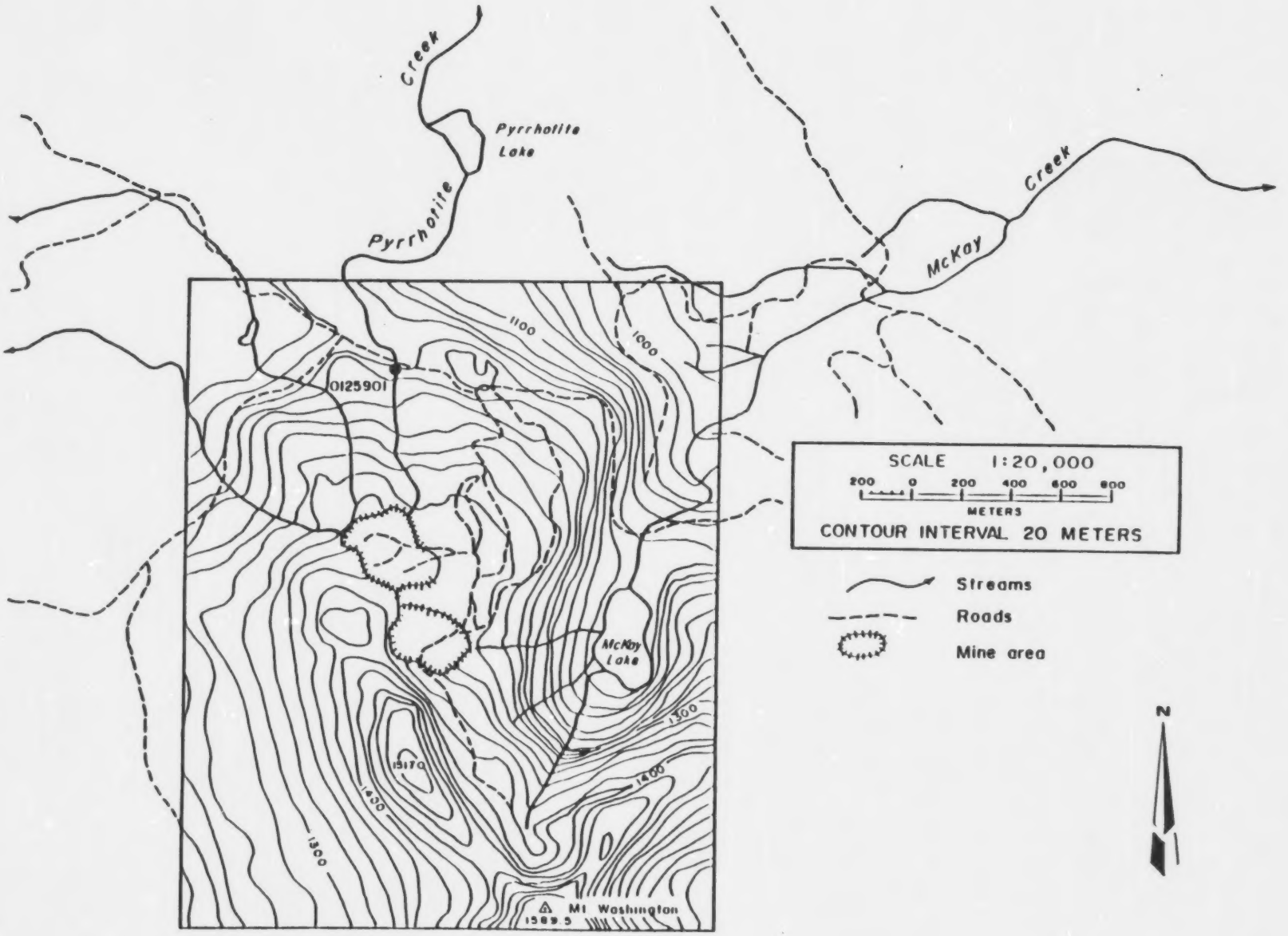
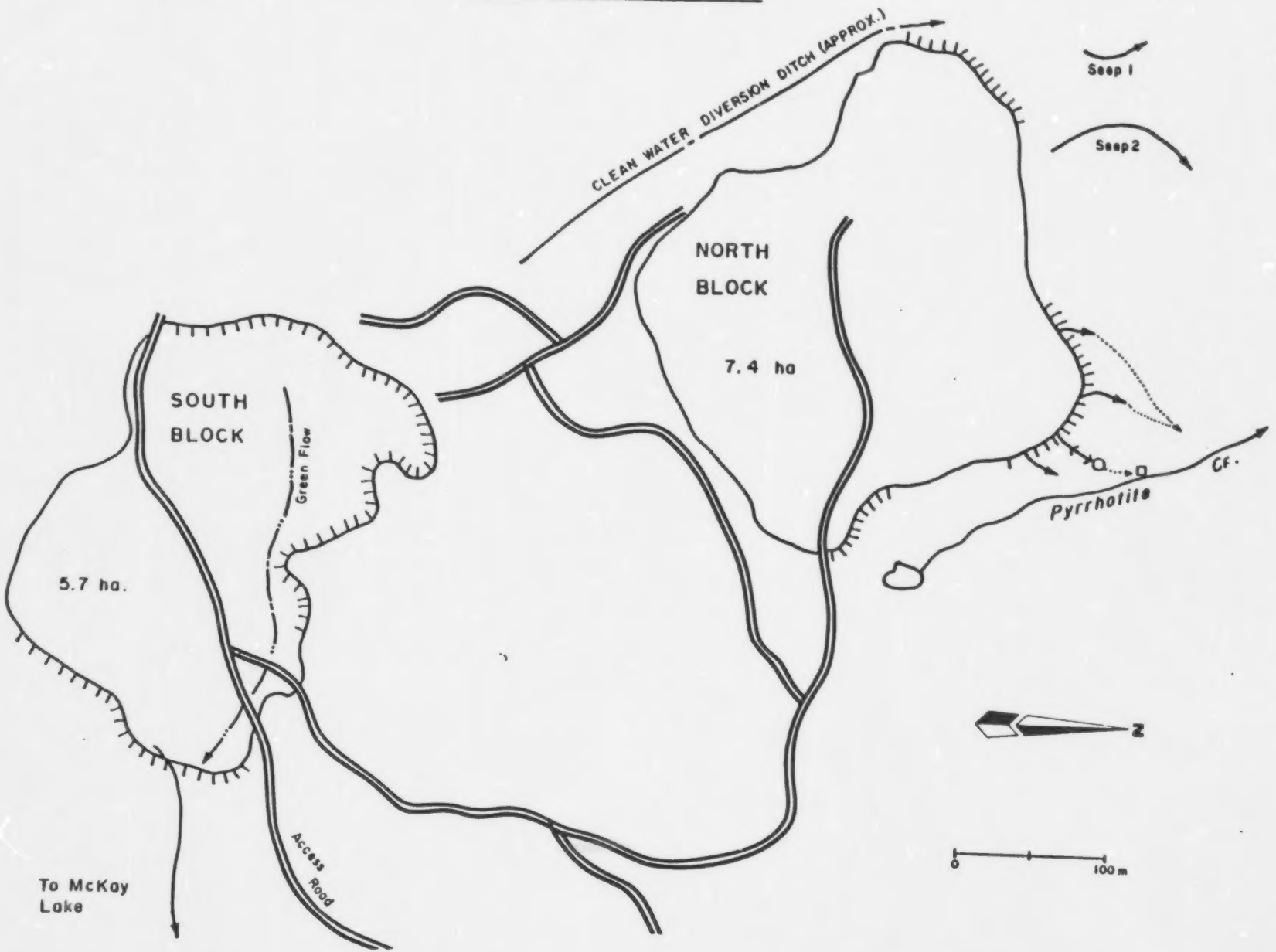


FIGURE 4

MT. WASHINGTON MINESITE



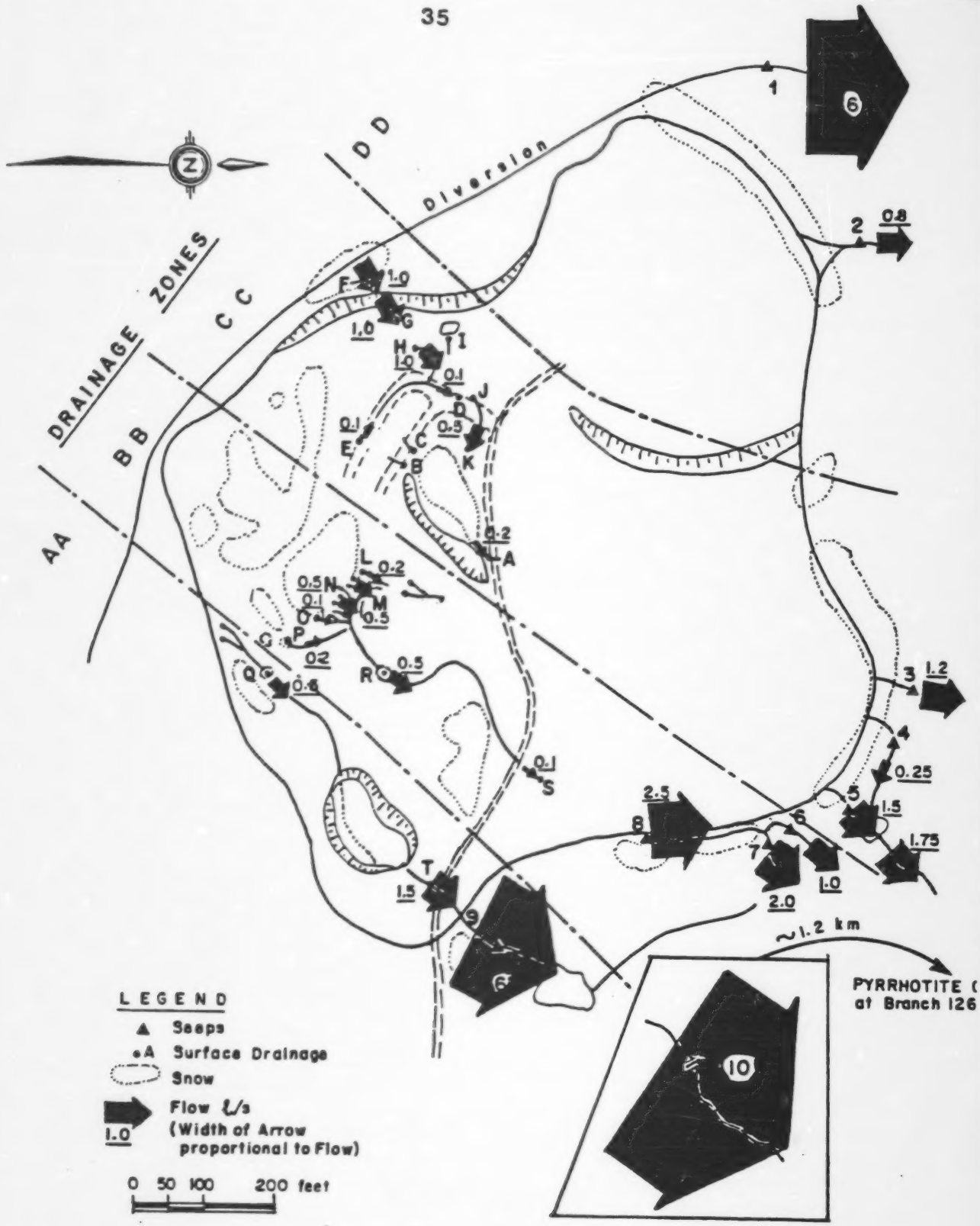


FIGURE 5 MOUNT WASHINGTON NORTH WASTE ROCK DUMP - SURFACE DRAINAGE AND SEEPAGE FLOWS, June 24- 25, 1986 (From Keith Ferguson (1986), EPS)

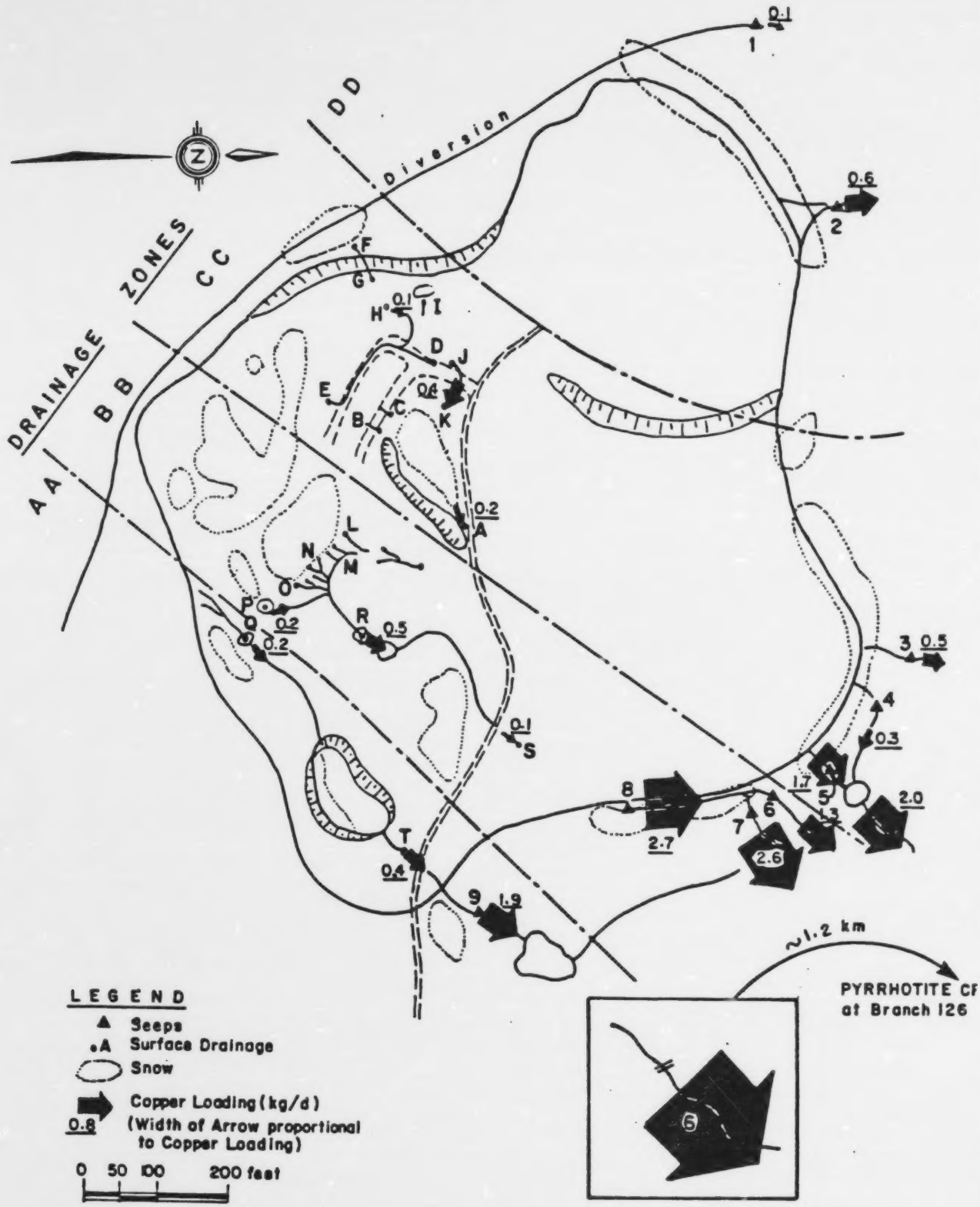
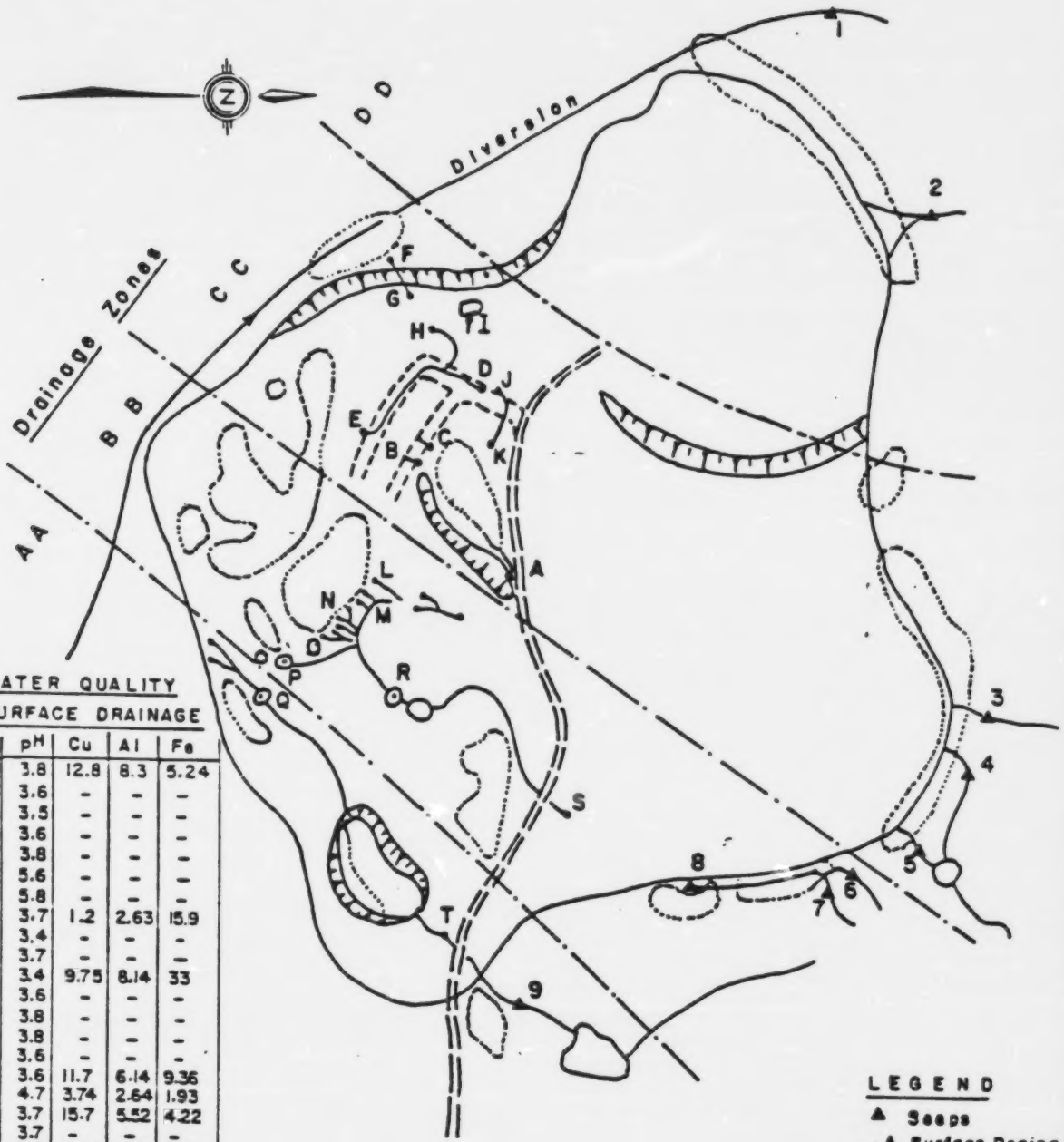


FIGURE 6 MOUNT WASHINGTON NORTH WASTE ROCK DUMP - SURFACE DRAINAGE AND SEEPAGE COPPER LOADINGS, June 24-25, 1986
(From Keith Ferguson (1986), EPS)



WATER QUALITY

SURFACE DRAINAGE

	pH	Cu	Al	Fe
A	3.8	12.8	8.3	5.24
B	3.6	-	-	-
C	3.5	-	-	-
D	3.6	-	-	-
E	3.8	-	-	-
F	5.6	-	-	-
G	5.8	-	-	-
H	3.7	1.2	2.63	15.9
I	3.4	-	-	-
J	3.7	-	-	-
K	3.4	9.75	8.14	33
L	3.6	-	-	-
M	3.8	-	-	-
N	3.8	-	-	-
O	3.6	-	-	-
P	3.6	11.7	6.14	9.36
Q	4.7	3.74	2.64	1.93
R	3.7	15.7	5.52	4.22
S	3.7	-	-	-
T	6.4	4.62	1.89	292
SEEP				
1	6.0	0.235	0.5	0.065
2	5.5	9.29	15.2	0.704
3	3.5	5.81	8.66	4.5
4	4.2	12.9	19.7	3.07
5	3.8	13.2	23.2	7.7
6	3.9	-	-	-
7	3.9	15.2	12.2	2.53
8	4.0	12.7	10.7	2.51
9	6.0	3.64	1.19	1.77

FIGURE 7 MOUNT WASHINGTON NORTH WASTE ROCK DUMP - SURFACE DRAINAGE AND SEEPAGE QUALITY – June 24-25, 1986 (From Keith Ferguson (1986), EPS)

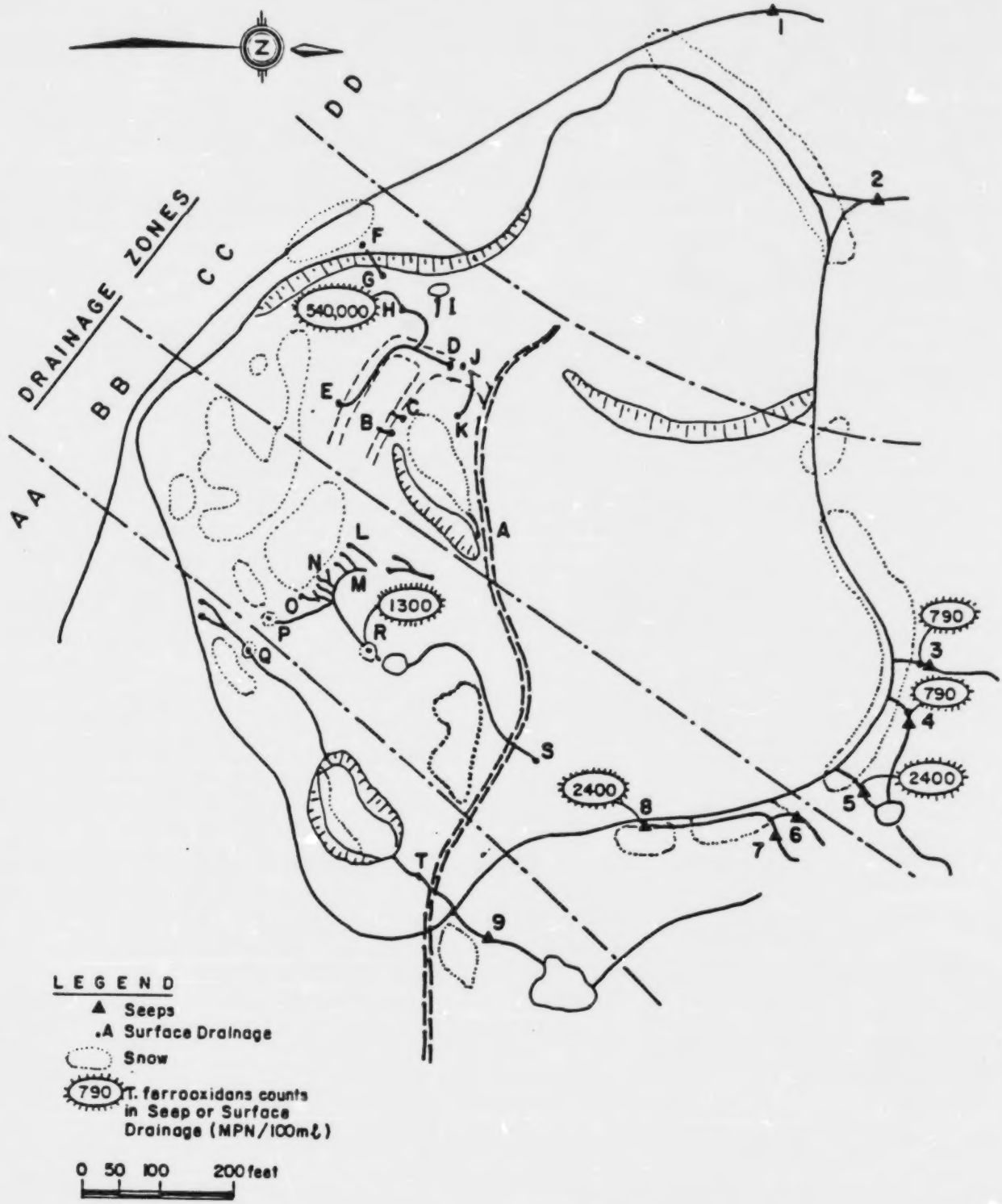
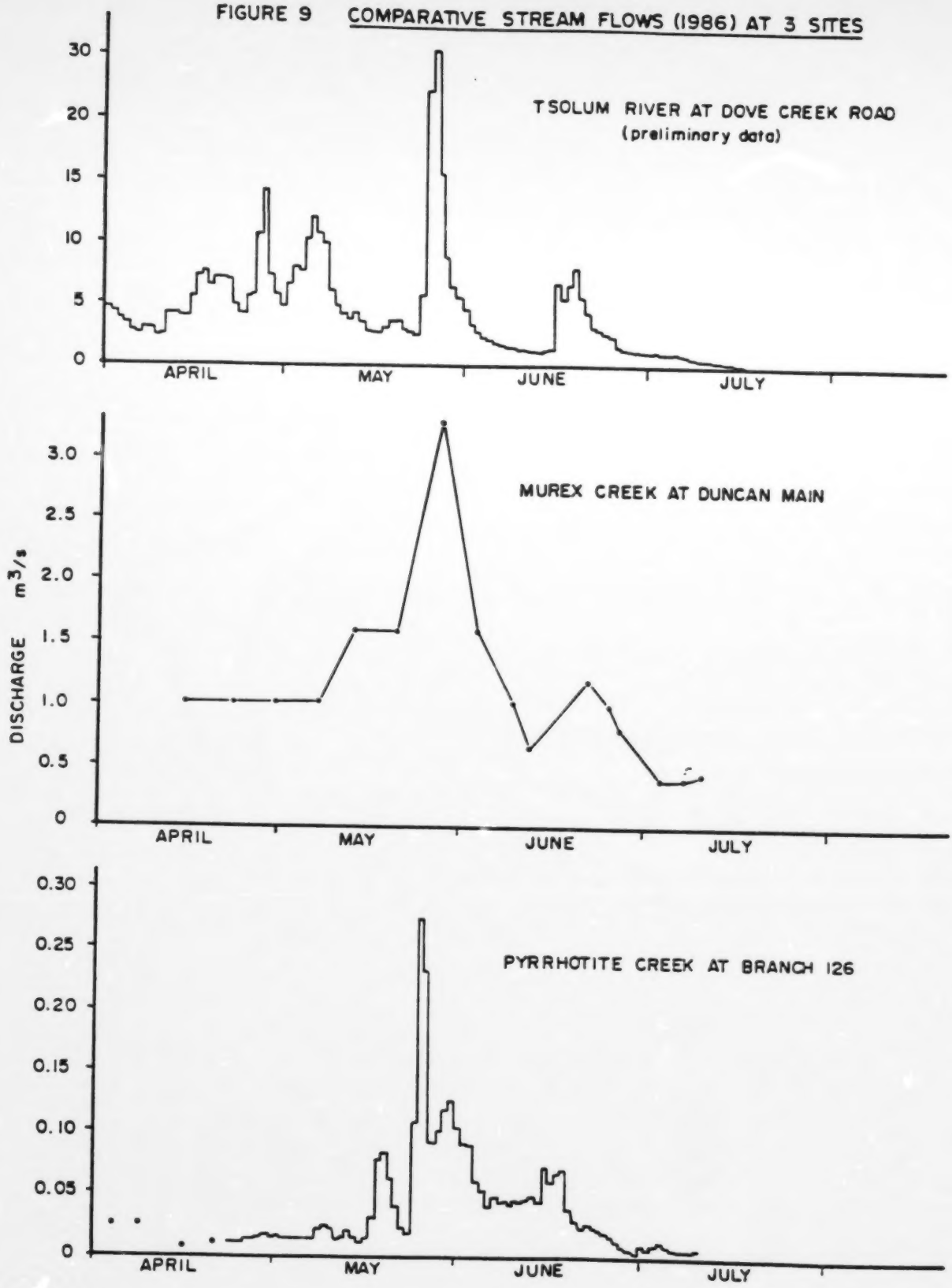


FIGURE 8 MOUNT WASHINGTON NORTH WASTE ROCK DUMP - SURFACE DRAINAGE AND SEEPAGE THIOBACILLUS FERROOXIDANS COUNTS

(From Keith Ferguson (1986), EPS)

FIGURE 9 COMPARATIVE STREAM FLOWS (1986) AT 3 SITES



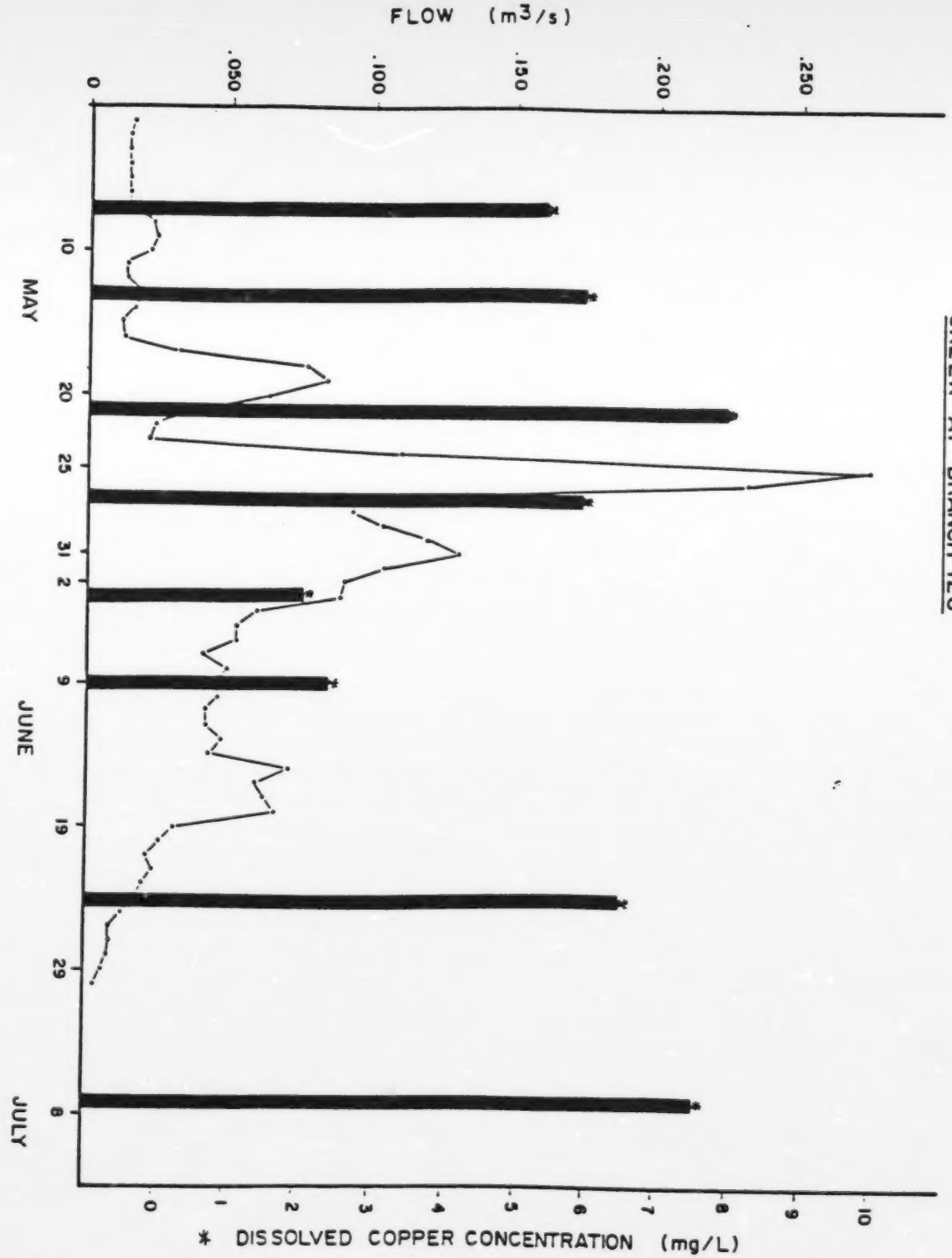


FIGURE 10 FLOW AND DISSOLVED COPPER CONCENTRATION IN PYRRHOTITE CREEK AT BRANCH 126

FIGURE II SNOW SURVEY OBSERVATIONS
WATER MANAGEMENT PROGRAM
MINISTRY OF ENVIRONMENT & PARKS

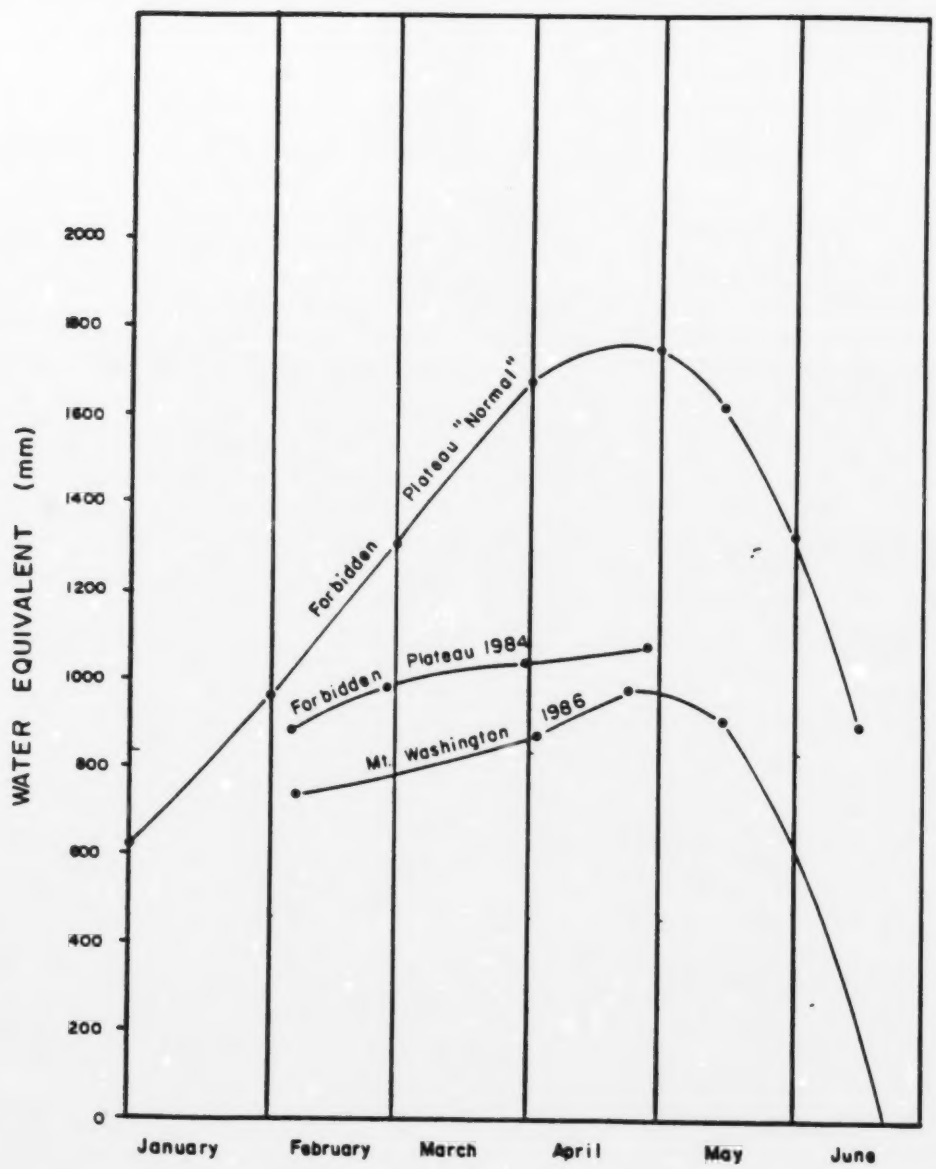
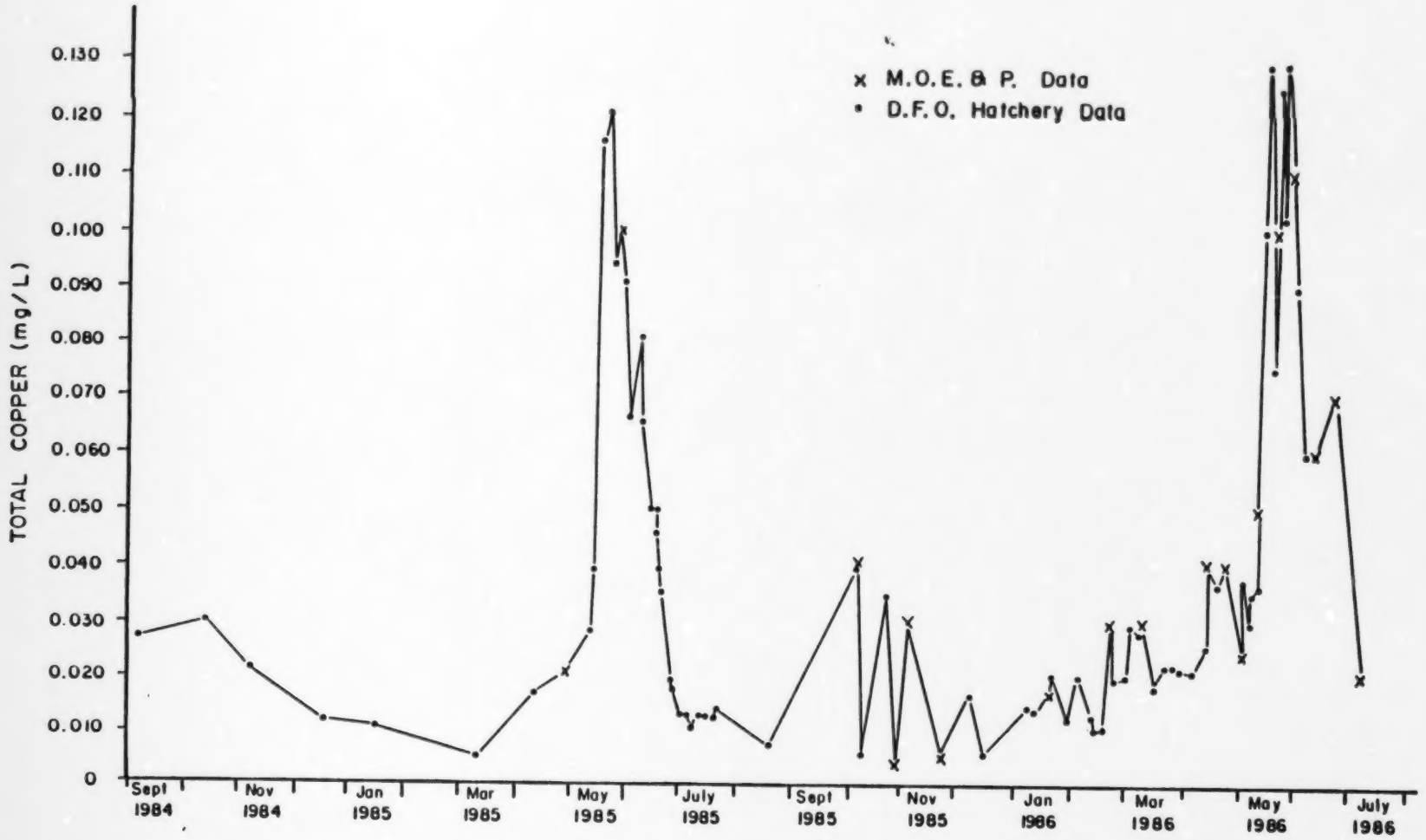


FIGURE 12 TOTAL COPPER CONCENTRATION, SEPTEMBER 1984 TO JULY 1986
MUREX CREEK AT DUNCAN BAY MAINLINE



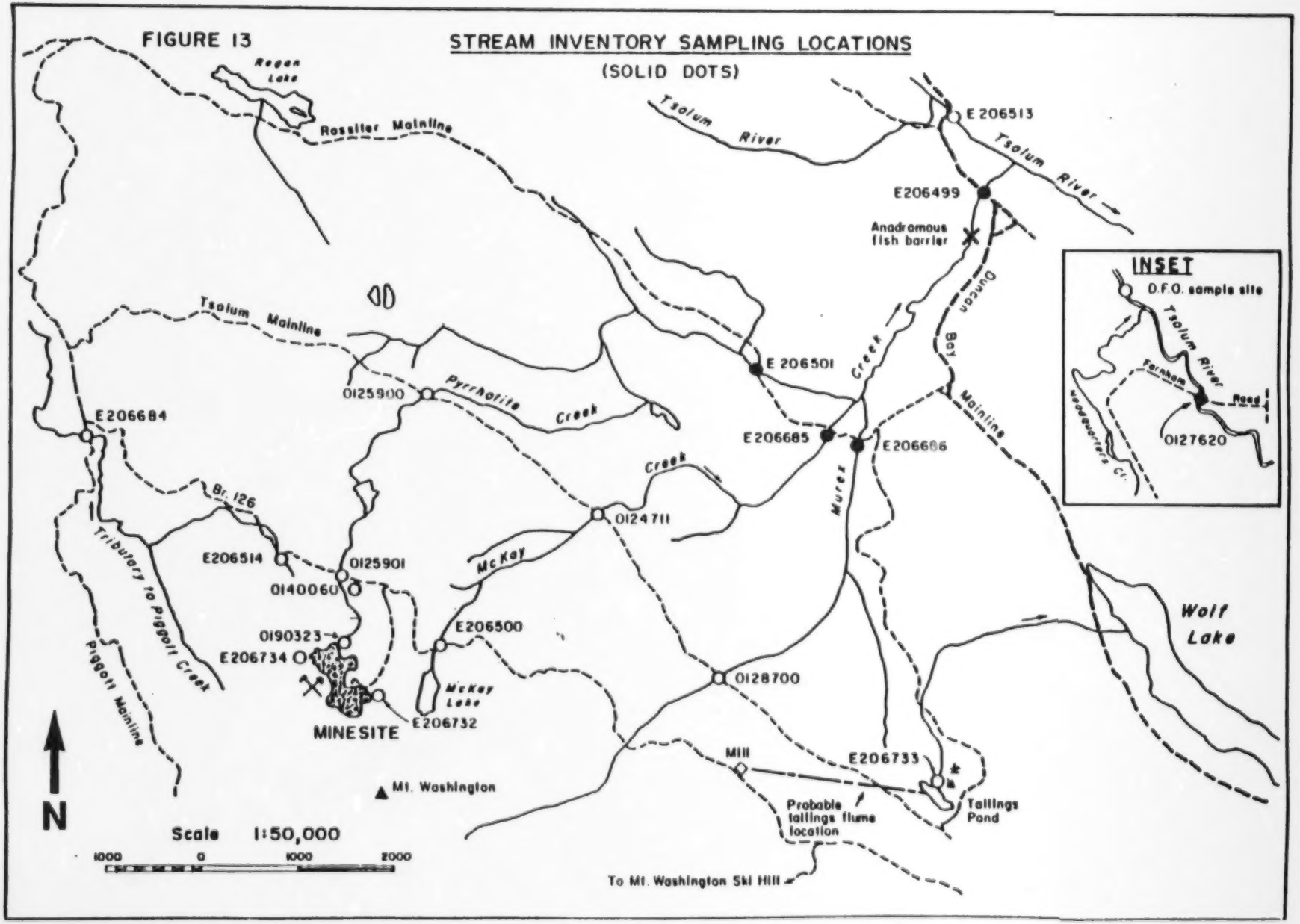


FIGURE 13
STREAM INVENTORY SAMPLING LOCATIONS
(SOLID DOTS)
Regan Lake
Rossiter Mainline
Tsolum River
E 206513
Tsolum River
E206499
Anadromous fish barrier
Duncan Bay Mainline
Duncan Creek
INSET
D.F.O. sample site
Tsolum River
Farnham Road
0127620
Woodwards Cr.
Tsolum Mainline
E 206501
0125900
Pyrrhotite Creek
E206684
E206685
E206686
Murex Creek
Br. 126
0124711
Tributary to Piggott Creek
E206514
0125901
0140060
McKay Creek
0190323
E206734
E206500
Piggott Mainline
McKay Lake
E206732
MINESITE
0128700
Wolf Lake
Mill
E206733
Mt. Washington
Probable tailings flume location
Tailings Pond
To Mt. Washington Ski Hill
N
Scale 1:50,000
1000 0 1000 2000

FIGURE 14

MACROINVERTEBRATE SAMPLING LOCATIONS
(SOLID DOTS)

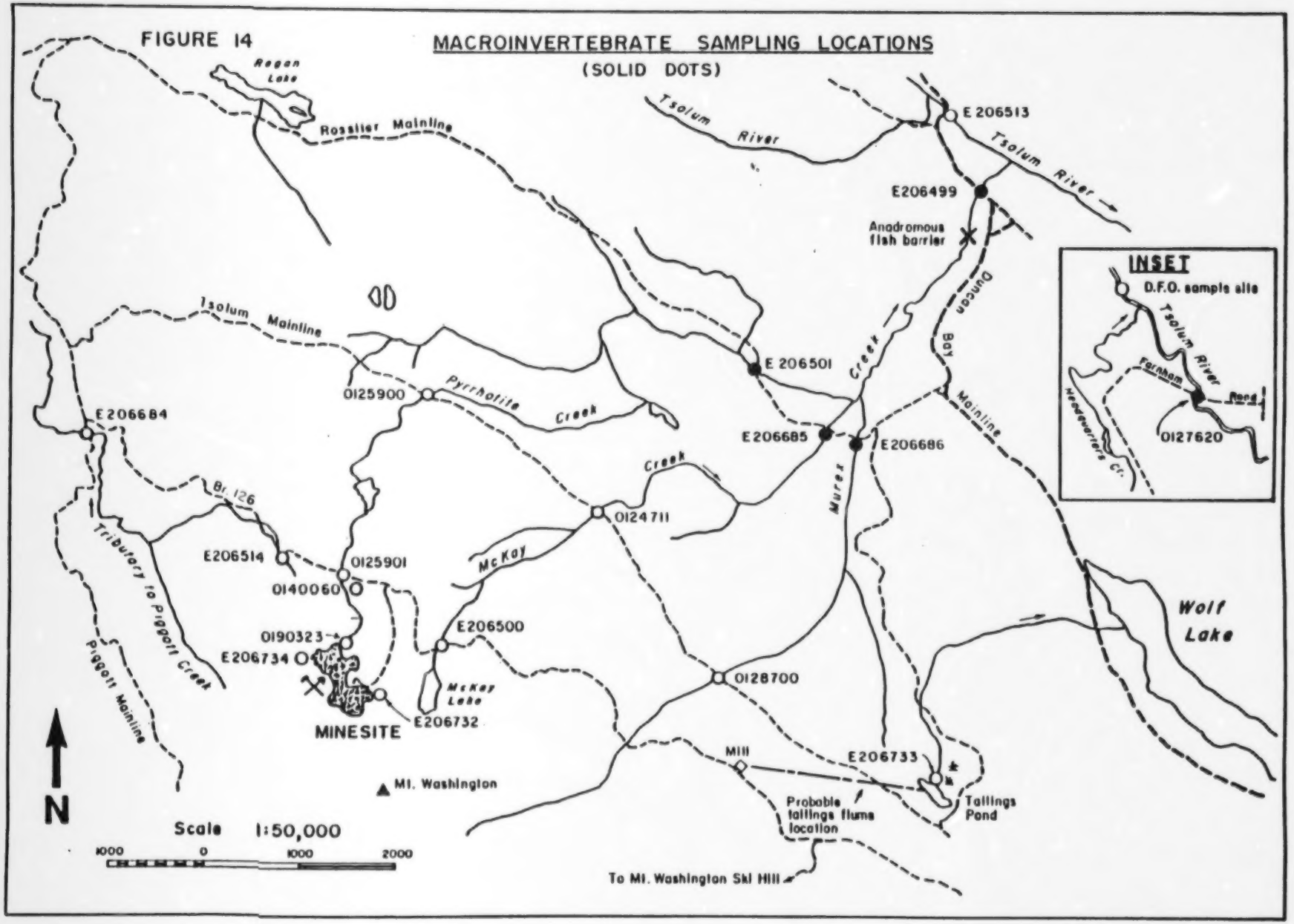


FIGURE 15 IN-SITU STEELHEAD EGG BIOASSAY LOCATIONS

(SOLID DOTS)

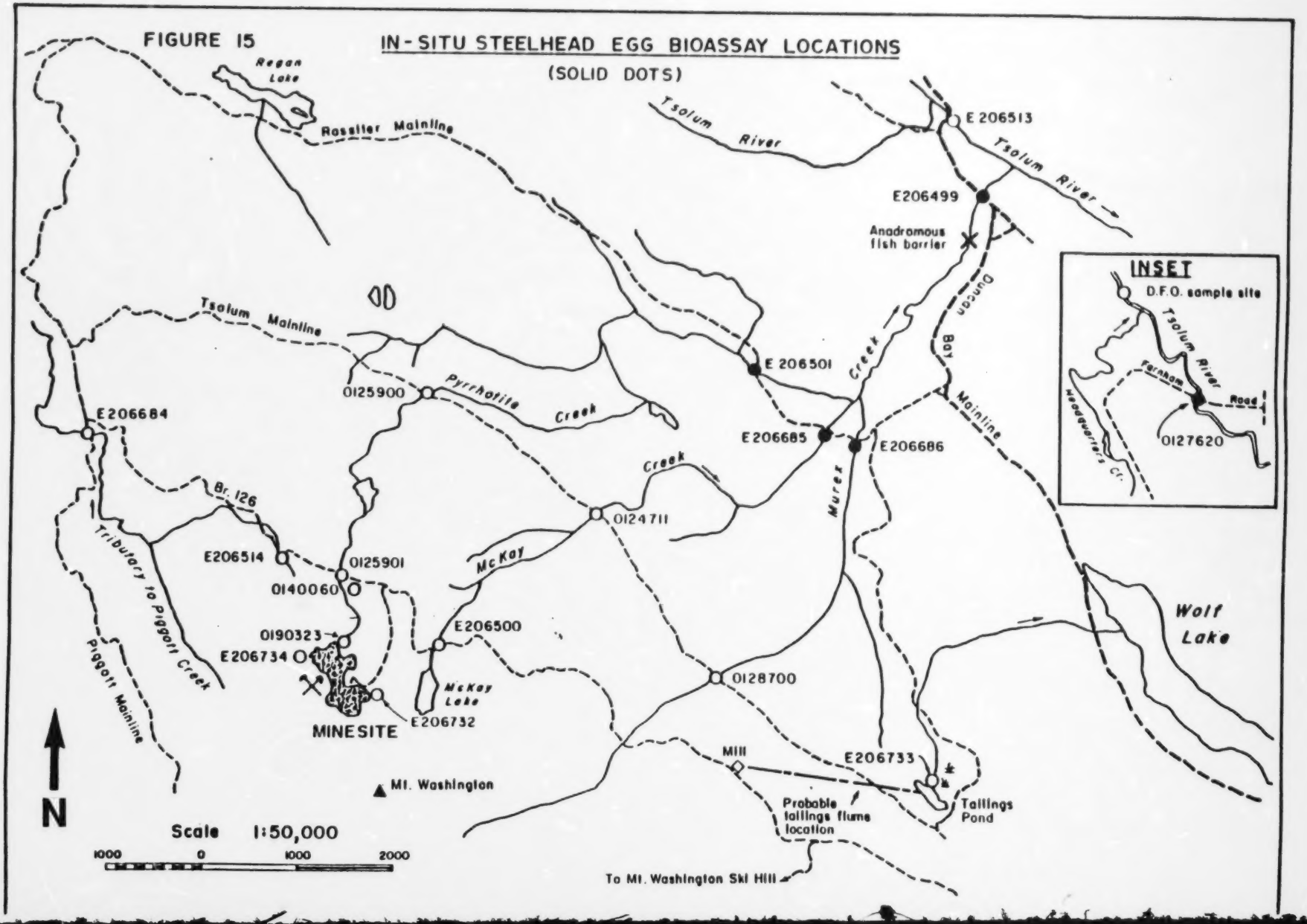


FIGURE 16

IN-SITU FISH BIOASSAY LOCATIONS
(SOLID DOTS)

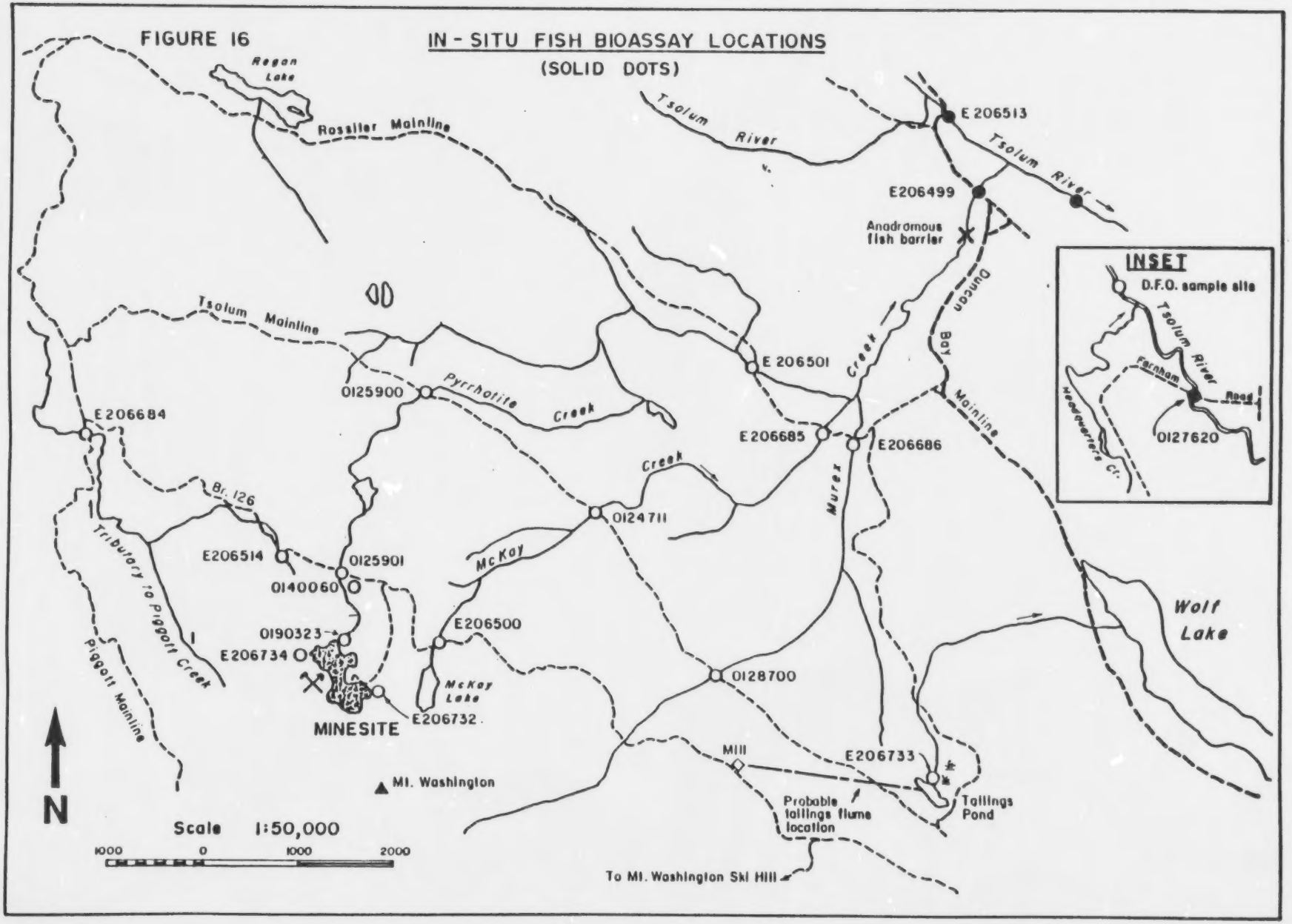


TABLE 1

PRELIMINARY GUAGE HEIGHT - DISCHARGE FOR PYRRHOTITE CREEK AT BRANCH 126
MINISTRY OF ENVIRONMENT AND PARKS - WATER MANAGEMENT PROGRAM

STATION NO. 08HBB09 WATER QUALITY STATION 0125901

	APRIL		MAY		JUNE		JULY	
Day	Guage Height [m.]	Discharge [CMS]	Guage Height [m.]	Discharge [CMS]	Guage Height [m.]	Discharge [CMS]	Guage Height [m.]	Discharge [CMS]
1			0.160	0.015	0.357	0.101	0.123	0.008
2			0.159	0.014	0.336	0.090	0.107	0.005
3			0.157	0.014	0.334	0.089	0.122	0.008
4			0.159	0.014	0.285	0.060	0.132	0.009
5			0.158	0.014	0.270	0.053	0.105	0.005
6			0.158	0.014	0.270	0.053	0.088	0.003
7			0.157	0.014	0.245	0.041	0.084	0.003
8			0.184	0.021	0.264	0.050	0.084	0.003
9			0.191	0.023	0.255	0.046	0.082	0.003
10			0.184	0.021	0.257	0.047	0.100	0.004
11			0.154	0.013	0.250	0.043	0.083	0.003
12			0.159	0.014	0.250	0.043	0.078	0.002
13			0.179	0.020	0.261	0.048	0.079	0.002
14			0.160	0.015	0.251	0.044	0.114	0.006
15			0.145	0.011	0.307	0.072	0.113	0.006
16			0.147	0.012	0.285	0.060	0.093	0.003
17			0.221	0.032	0.292	0.064	0.139	0.010
18			0.315	0.077	0.300	0.068	0.119	0.007
19			0.325	0.084	0.218	0.031	0.099	0.004
20			0.291	0.064	0.204	0.026	0.088	0.003
21			0.238	0.039	0.187	0.022	0.081	0.003
22			0.197	0.024	0.196	0.024	0.076	0.003
23			0.185	0.021	0.182	0.020	0.067	0.002
24			0.365	0.110	0.169	0.017	0.064	0.001
25	0.144	0.011	0.527	0.275	0.153	0.013	0.059	0.001
26	0.146	0.011	0.492	0.232	0.133	0.009	0.055	0.000
27	0.149	0.012	0.340	0.093	0.131	0.009	0.052	0.000
28	0.151	0.012	0.340	0.093	0.125	0.008	0.051	0.000
29	0.155	0.013	0.355	0.103	0.113	0.006	0.048	0.000
30	0.161	0.015	0.375	0.119	0.101	0.004	0.055	0.000
31	0.160	0.014	0.392	0.131				
TOTAL				1.746		1.261		0.104
MEAN				0.056		0.042		0.003
DAM^3				151		109		8.99
MAX				0.275		0.104		0.010
MIN				0.011		0.004		0.000

TABLE 2

MISCELLANEOUS STREAMFLOW MEASUREMENTS

MINISTRY OF ENVIRONMENT AND PARKS - WATER MANAGEMENT PROGRAM

DATE 1986	MUREX CREEK AT DUNCAN BAY MAINLINE (E206499) m^3/sec	TSOLUM R AT DUNCAN BAY MAINLINE (E206513) m^3/sec	PYRRHOTITE CK AT ROSSITER MAINLINE (E206501) m^3/sec	MUREX CREEK AT ROSSITER MAINLINE (E206686) m^3/sec	McKAY CREEK AT ROSSITER MAINLINE (E206685) m^3/sec
JUN 2	1.62	0.105	0.205	0.793	0.305
JUN 12	0.634	0.044	0.104		
JUN 26	0.795	0.133	0.134		
JUL 10	0.449	0.049	0.069		
JUL 31	0.098	0.015	0.011		
AUG 14	0.014	0.005	0.000		
AUG 28	0.011	0.006	0.002		

NOTE: See Figure 2 for locations

SUMMARY OF SUMMARY DATA

TABLE 3

WASTE MANAGEMENT PROGRAM DATA

1985 to July 1, 1986

0125901 Pyrrhotite Creek at Br. 126

	Al tot.	Al dis.	Cu tot.	Cu dis.	Fe tot.	Fe dis.	Zn tot.	Zn dis.
average	8.11	7.72	8.01	7.92	0.67	.70	0.24	.23
maximum	13.20	12.20	12.90	12.90	1.51	1.39	0.41	.40
minimum	1.92	1.83	3.32	3.32	0.01	.22	0.06	.06

E206501 Pyrrhotite at Rossiter Main Road

	Al tot.	Al dis.	Cu tot.	Cu dis.	Fe tot.	Fe dis.	Zn tot.	Zn dis.
average	0.17	0.196	0.20	0.21	0.05	0.04	0.01	0.01
maximum	0.45	0.161	0.91	0.85	0.14	0.09	0.03	0.02
minimum	0.08	0.03	0.02	0.02	0.01	0.01	0.01	0.01

E206499 Murex Creek at Duncan Main Road

	Al tot.	Al dis.	Cu tot.	Cu dis.	Fe tot.	Fe dis.	Zn tot.	Zn dis.
average	0.22	0.09	0.04	0.04	0.337	0.05	0.01	0.01
maximum	1.67	0.20	0.11	0.10	2.41	0.15	0.01	0.01
minimum	0.02	0.05	0.003	0.003	0.01	<0.01	<0.01	<0.01

0127620 Tsolum River at Farnham Road Bridge

	Al tot.	Al dis.	Cu tot.	Cu dis.	Fe tot.	Fe dis.	Zn tot.	Zn dis.
average	0.179	0.07	0.02	0.016	0.286	0.088	0.01	
maximum	2.32	0.27	0.10	0.040	3.55	0.26	0.02	
minimum	0.02	0.03	0.003	0.003	0.04	<0.01	<0.005	

0127621 Tsolum River U/S Puntledge River

	Al tot.	Al dis.	Cu tot.	Cu dis.	Fe tot.	Fe dis.	Zn tot.	Zn dis.
average	0.308	0.06	0.021	0.010	0.441	0.097	0.021	0.01
maximum	1.94	0.22	0.02	0.02	2.61	0.29	0.03	0.01
minimum	0.02	<0.02	<0.001	<0.001	0.11	0.04	0.01	0.01

E206513 Tsolum River at the Duncan Bay Main Road (U/S of Murex Creek)

	Al tot.	Al dis.	Cu tot.	Cu dis.	Fe tot.	Fe dis.	Zn tot.	Zn dis.
average	0.147	0.06	0.004	0.003	0.465	0.15	0.02	<0.01
maximum	1.73	0.14	0.02	0.02	2.52	0.37	0.01	<0.01
minimum	0.02	<0.02	<0.001	<0.001	0.05	0.04	<0.01	<0.01

SELECTED DATA FROM SCATTERED SITES
(*indicates dissolved)

TABLE 4

Site/Date	pH	dissolved Sulphate mg/L	total Al mg/L	total Cu mg/L	total Fe mg/L	total Zn mg/L
E206733 Tailings Pond Outlet.						
85/06/26			.82	.06	1.53	< .005
85/05/30	6.7	38	.11	.06	.57	< .005
86/05/21			.10*	.09*	.07*	.01*
E206500 McKay Creek at Mill Road						
85/06/26	6.7	12.6	< .06	.020	.04	< .005
85/07/23			.03	.006	.02	< .005
85/10/03			< .02	.02	.09	< .01
85/10/31			.06	.02	.06	< .01
86/07/07				.02		
86/08/13				.007		
E206685 McKay Creek at Rossiter M/L						
85/05/01	6.7	1.9	.15	.004	.45	.005
86/05/13			.12	.003	.04	.02
86/05/21			.10*	.002*	.01*	< .005*
86/05/27			.14*	.009*	.04*	< .01*
86/06/03			.07*	.02*	.03*	< .01*
0124711 McKay Creek at Tsolum M/L						
85/05/30	6.7	5.3	.12	.006	.03	< .005
E206732 Tribs to McKay Lake						
85/06/26			.10	.11	.05	.012
85/06/26			.03*	.41*	.02*	.04*
85/10/08			< .02	.13	.01	.03
85/07/23			.05	.13	.03	.03
86/06/09			.08	.23	.07	.02
E206684 Trib to Piggott Creek						
85/05/01	7.5	2.4	.05	.003	.07	< .005
85/05/30	7.0	3.7	.11	.010	.03	< .005
86/04/30			.11	.004	.05	< .01
86/05/27			.08*	.02*	.04*	< .01*
86/06/24						
Seep 1						
85/06/26			5.68	5.74	.19	.13
85/07/23			2.45	2.54	.12	.07
Sister Cr.						
86/06/09			.16	.11	.06	.02
Seep 2						
85/06/26			7.18	6.01	.29	.13

Table 4 Continued

Site/Date	pH	dissolved Sulphate mg/L	total Al mg/L	total Cu mg/L	total Fe mg/L	total Zn mg/L
0190329						
85/05/30	3.4	156	7.84	12.2	4.41	.23
85/07/23			26.5	15.3	5.06	.63
86/06/24	3.2	333	21.2	19.5	8.23	.58
seep-126						
85/06/26			7.18	6.01	.29	.13
seep-pond seep						
85/06/26			7.70	6.83	3.28	.22
pond seep						
85/07/23			.08	.51	.16	.04
seep above pond						
86/06/09			.69	3.66	.83	.07
0140060 Drainage ditch 126 road u/s of swamp						
85/09/12	5.2	8.4	.29	.04	.89	.01
E206734 Diversion ditch						
86/06/09			.15	.02	.12	< .01
86/06/24			.13	.02	.12	< .01
0125900 Pyrrhotite Creek at Tsolum m/L						
82/11/04	4.6		.95	1.23	.15	.04
84/08/01	4.4	14.8	.71	1.05	.28	.04
84/10/16	4.9	23.0	.27	1.32	.06	.04
85/06/26			.87	1.66	.09	.025
85/09/18	4.9	23.8	.68	1.38	.10	.04
Murex at Mill Road						
85/07/23			.03	< .001	.04	< .005
E206686 Murex at Rossiter						
86/05/13			.09	.011	.09	.005
86/05/21			.06	.005	.02	< .005
Swamp at North Edge of Tailing Pond (Murex Drainage)						
85/06/26			.07	.14	8.47	< .005

WASTE MANAGEMENT PROGRAM

TABLE 5

Site Number: 0125901 Pyrrhotite Creek at Branch 126

Date	Aluminum total	Copper total	Iron total	Zinc total	Hardness total
850530	2.06 mg/L	3.60 mg/L	0.88 mg/L	0.07 mg/L	18.00 mg/L
850723	6.58 mg/L	7.23 mg/L	0.31 mg/L	0.18 mg/L	73.90 mg/L
851003	13.20 mg/L	10.40 mg/L	0.35 mg/L	0.40 mg/L	151.00 mg/L
851010	7.28 mg/L	6.10 mg/L	0.47 mg/L	0.23 mg/L	82.00 mg/L
851023	12.20 mg/L	12.90 mg/L	1.14 mg/L	0.41 mg/L	107.00 mg/L
851031	11.90 mg/L	9.93 mg/L	0.43 mg/L	0.37 mg/L	101.00 mg/L
851106	11.80 mg/L	9.60 mg/L	0.53 mg/L	0.36 mg/L	109.00 mg/L
851112	11.40 mg/L	10.10 mg/L	0.34 mg/L	0.36 mg/L	111.00 mg/L
851126	9.80 mg/L	9.07 mg/L	0.29 mg/L	0.33 mg/L	110.00 mg/L
860206	8.51 mg/L	7.37 mg/L	0.33 mg/L	0.25 mg/L	80.30 mg/L
860403	8.24 mg/L	7.36 mg/L	0.23 mg/L	0.21 mg/L	73.60 mg/L
860416	7.78 mg/L	7.10 mg/L	0.37 mg/L	0.22 mg/L	79.00 mg/L
860422	9.68 mg/L	9.86 mg/L	1.29 mg/L	0.27 mg/L	82.80 mg/L
860423	10.10 mg/L	9.59 mg/L	1.02 mg/L	0.29 mg/L	85.10 mg/L
860430	10.20 mg/L	8.08 mg/L	0.36 mg/L	0.25 mg/L	80.30 mg/L
860507	7.00 mg/L	6.53 mg/L	0.74 mg/L	0.21 mg/L	71.30 mg/L
860513	7.82 mg/L	7.29 mg/L	0.80 mg/L	0.22 mg/L	69.10 mg/L
860521	6.36 mg/L	9.04 mg/L	1.51 mg/L	0.20 mg/L	53.00 mg/L
860527	4.59 mg/L	7.34 mg/L	1.41 mg/L	0.14 mg/L	35.50 mg/L
860603	1.92 mg/L	3.32 mg/L	0.75 mg/L	0.06 mg/L	17.20 mg/L
860609	2.15 mg/L	3.49 mg/L	0.60 mg/L	0.06 mg/L	20.00 mg/L
860624	5.06 mg/L	7.79 mg/L	1.32 mg/L	0.17 mg/L	47.20 mg/L
860707	6.82 mg/L	8.66 mg/L	0.73 mg/L	0.19 mg/L	66.30 mg/L
860813	10.70 mg/L	9.65 mg/L	0.40 mg/L	0.27 mg/L	124.00 mg/L
860915	9.61 mg/L	8.91 mg/L	0.28 mg/L	0.28 mg/L	150.00 mg/L
AVERAGE	8.114	8.012	0.675	0.24	80
MAXIMUM	13.20	12.90	1.51	0.41	151
MINIMUM	1.92	3.32	0.23	0.06	18

Date	Aluminum dissolved	Copper dissolved	Iron dissolved	Zinc dissolved	Hardness dissolved
851023	12.20 mg/L	12.90 mg/L	1.09 mg/L	0.40 mg/L	107.00 mg/L
851031	11.50 mg/L	9.93 mg/L	0.43 mg/L	0.37 mg/L	101.00 mg/L
851106	11.70 mg/L	9.50 mg/L	0.53 mg/L	0.34 mg/L	98.90 mg/L
851112	11.30 mg/L	10.10 mg/L	0.34 mg/L	0.36 mg/L	111.00 mg/L
851126	9.80 mg/L	8.74 mg/L	0.25 mg/L	0.31 mg/L	108.00 mg/L
860403	8.24 mg/L	7.36 mg/L	0.23 mg/L	0.20 mg/L	68.50 mg/L
860416	7.53 mg/L	6.54 mg/L	0.22 mg/L	0.21 mg/L	70.20 mg/L
860423	9.08 mg/L	9.01 mg/L	0.97 mg/L	0.27 mg/L	79.60 mg/L
860430	9.05 mg/L	7.72 mg/L	0.36 mg/L	0.23 mg/L	77.50 mg/L
860507	7.00 mg/L	6.53 mg/L	0.74 mg/L	0.20 mg/L	71.30 mg/L
860513	7.54 mg/L	7.29 mg/L	0.77 mg/L	0.22 mg/L	69.10 mg/L
860521	6.36 mg/L	9.04 mg/L	1.39 mg/L	0.20 mg/L	50.60 mg/L
860527	4.35 mg/L	7.00 mg/L	1.33 mg/L	0.13 mg/L	34.70 mg/L
860603	1.83 mg/L	3.32 mg/L	0.66 mg/L	0.06 mg/L	16.90 mg/L
860609	2.15 mg/L	3.43 mg/L	0.58 mg/L	0.06 mg/L	19.30 mg/L
860624	4.91 mg/L	7.57 mg/L	1.31 mg/L	0.16 mg/L	47.0 mg/L
860707	6.73 mg/L	8.66 mg/L	0.73 mg/L	0.19 mg/L	66.30 mg/L
AVERAGE	7.722	7.920	0.702	0.23	70.4
MAXIMUM	12.20	12.90	1.39	0.40	111
MINIMUM	1.83	3.32	0.22	0.06	16.9

WASTE MANAGEMENT PROGRAM

TABLE 6

Site Number: E206501 Pyrrhotite Creek at Rossiter Main Road

Date	Aluminum total	Copper total	Iron total	Zinc total	Hardness total
851031	0.10 mg/L	0.06 mg/L	0.02 mg/L	<0.01 mg/L	8.8 mg/L
851106	0.15 mg/L	0.10 mg/L	<0.01 mg/L	0.01 mg/L	9.6 mg/L
851112	0.11 mg/L	0.08 mg/L	0.02 mg/L	<0.01 mg/L	11.4 mg/L
851126	0.09 mg/L	0.07 mg/L	0.04 mg/L	<0.01 mg/L	12.5 mg/L
860128	0.11 mg/L	0.021 mg/L	0.05 mg/L	<0.01 mg/L	6.1 mg/L
860225	0.24 mg/L	0.10 mg/L	0.14 mg/L	<0.01 mg/L	6.4 mg/L
860310	0.15 mg/L	0.08 mg/L	0.04 mg/L	<0.01 mg/L	10.1 mg/L
860416	0.15 mg/L	0.07 mg/L	0.04 mg/L	<0.01 mg/L	8.3 mg/L
860423	0.19 mg/L	0.13 mg/L	0.04 mg/L	<0.01 mg/L	6.9 mg/L
860430	0.17 mg/L	0.06 mg/L	0.03 mg/L	<0.01 mg/L	8.6 mg/L
860513	0.08 mg/L	0.17 mg/L	0.05 mg/L	0.02 mg/L	11.6 mg/L
860521	0.42 mg/L	0.48 mg/L	0.12 mg/L	0.02 mg/L	11.1 mg/L
860527	0.23 mg/L	0.22 mg/L	0.03 mg/L	<0.01 mg/L	13.6 mg/L
860603	0.45 mg/L	0.91 mg/L	0.11 mg/L	0.03 mg/L	13.2 mg/L
860609	0.37 mg/L	0.74 mg/L	0.08 mg/L	0.02 mg/L	10.0 mg/L
860624	0.16 mg/L	0.21 mg/L	0.05 mg/L	0.02 mg/L	
860707	0.07 mg/L	0.16 mg/L	0.07 mg/L	0.01 mg/L	
860813	0.05 mg/L	0.05 mg/L	0.01 mg/L	<0.01 mg/L	
860915	<0.02 mg/L	0.03 mg/L	<0.01 mg/L	<0.01 mg/L	
AVERAGE	0.174	0.202	0.053	0.013	9.9
MAXIMUM	0.45	0.91	0.14	0.03	13.6
MINIMUM	<0.02	0.021	<0.01	<0.01	6.1

Date	Aluminum dissolved	Copper dissolved	Iron dissolved	Zinc dissolved	Hardness dissolved
851031	0.08 mg/L	0.06 mg/L	0.02 mg/L	<0.01 mg/L	8.7 mg/L
851106	0.09 mg/L	0.08 mg/L	<0.01 mg/L	0.01 mg/L	9.4 mg/L
851112	0.11 mg/L	0.08 mg/L	0.02 mg/L	<0.01 mg/L	11.4 mg/L
851126	0.09 mg/L	0.07 mg/L	0.04 mg/L	0.01 mg/L	12.3 mg/L
860128	0.11 mg/L	0.021 mg/L	0.04 mg/L	<0.01 mg/L	5.6 mg/L
860225	0.15 mg/L	0.10 mg/L	0.05 mg/L	<0.01 mg/L	5.1 mg/L
860310	0.15 mg/L	0.07 mg/L	0.04 mg/L	<0.01 mg/L	6.4 mg/L
860416	0.15 mg/L	0.07 mg/L	0.03 mg/L	<0.01 mg/L	6.7 mg/L
860423	0.10 mg/L	0.12 mg/L	0.02 mg/L	<0.01 mg/L	8.1 mg/L
860430	0.11 mg/L	0.06 mg/L	0.03 mg/L	<0.01 mg/L	6.7 mg/L
860513	0.08 mg/L	0.17 mg/L	0.03 mg/L	<0.01 mg/L	8.6 mg/L
860521	0.07 mg/L	0.56 mg/L	0.06 mg/L	0.02 mg/L	11.5 mg/L
860527	0.16 mg/L	0.22 mg/L	0.04 mg/L	<0.01 mg/L	10.8 mg/L
860603	0.06 mg/L	0.85 mg/L	0.09 mg/L	0.02 mg/L	13.5 mg/L
860609	0.03 mg/L	0.62 mg/L	0.02 mg/L	0.02 mg/L	14.3 mg/L
860624	0.16 mg/L	0.21 mg/L	0.05 mg/L	0.02 mg/L	10.0 mg/L
AVERAGE	0.106	0.211	0.037	0.013	9.3
MAXIMUM	0.16	0.85	0.09	0.02	14.3
MINIMUM	0.03	0.021	0.01	<0.01	5.1

WASTE MANAGEMENT PROGRAM

TABLE 7

Site Number: E206499 Murex Creek at Duncan Main Road

Date	Aluminum total	Copper total	Iron total	Zinc total	Hardness total
851021	1.67 mg/L	0.04 mg/L	2.41 mg/L	0.01 mg/L	10.9 mg/L
851031	0.05 mg/L	0.003 mg/L	0.14 mg/L	<0.01 mg/L	12.3 mg/L
851106	0.08 mg/L	0.03 mg/L	0.04 mg/L	<0.01 mg/L	9.9 mg/L
851128	0.04 mg/L	0.005 mg/L	0.01 mg/L	<0.01 mg/L	11.7 mg/L
860125	0.10 mg/L	0.016 mg/L	0.05 mg/L	<0.01 mg/L	6.5 mg/L
860225	0.47 mg/L	0.03 mg/L	0.54 mg/L	<0.01 mg/L	6.5 mg/L
860310	0.11 mg/L	0.03 mg/L	0.04 mg/L	<0.01 mg/L	6.7 mg/L
860416	0.14 mg/L	0.04 mg/L	1.94 mg/L	<0.01 mg/L	10.7 mg/L
860423	0.12 mg/L	0.04 mg/L	0.11 mg/L	<0.01 mg/L	7.8 mg/L
860430	0.14 mg/L	0.023 mg/L	<0.01 mg/L	<0.01 mg/L	7.8 mg/L
860513	0.10 mg/L	0.05 mg/L	0.04 mg/L	<0.01 mg/L	7.3 mg/L
860521	0.17 mg/L	0.10 mg/L	0.11 mg/L	<0.01 mg/L	9.0 mg/L
860527	0.38 mg/L	0.10 mg/L	0.24 mg/L	<0.01 mg/L	8.2 mg/L
860603	0.12 mg/L	0.11 mg/L	0.09 mg/L	<0.01 mg/L	8.6 mg/L
860609	0.10 mg/L	0.06 mg/L	<0.01 mg/L	<0.01 mg/L	9.7 mg/L
860624	0.09 mg/L	0.07 mg/L	0.04 mg/L	<0.01 mg/L	9.4 mg/L
860707	0.05 mg/L	0.02 mg/L	0.02 mg/L	<0.01 mg/L	
860813	0.02 mg/L	0.012 mg/L	0.02 mg/L	0.02 mg/L	
AVERAGE	0.219	0.043	0.327	0.011	9.9
MAXIMUM	1.67	0.11	2.41	0.02	12.3
MINIMUM	0.02	0.003	<0.01	<0.01	6.5

Date	Aluminum dissolved	Copper dissolved	Iron dissolved	Zinc dissolved	Hardness dissolved
851021	0.20 mg/L	0.02 mg/L	0.14 mg/L	<0.01 mg/L	8.3 mg/L
851031	0.04 mg/L	0.003 mg/L	0.13 mg/L	<0.01 mg/L	12.2 mg/L
841106	0.08 mg/L	0.03 mg/L	0.05 mg/L	<0.01 mg/L	9.9 mg/L
851112	0.08 mg/L	0.02 mg/L	0.04 mg/L	<0.01 mg/L	11.3 mg/L
851112	0.08 mg/L	0.02 mg/L	0.02 mg/L	<0.01 mg/L	
851126			<0.01 mg/L	<0.01 mg/L	11.7 mg/L
860128	0.09 mg/L	0.016 mg/L	0.05 mg/L	<0.01 mg/L	6.1 mg/L
860225	0.12 mg/L	0.030 mg/L	0.07 mg/L	<0.01 mg/L	5.4 mg/L
860310	0.11 mg/L	0.02 mg/L	0.04 mg/L	<0.01 mg/L	6.7 mg/L
860416	0.09 mg/L	0.04 mg/L	0.03 mg/L	<0.01 mg/L	6.6 mg/L
860423	0.08 mg/L	0.04 mg/L	0.04 mg/L	<0.01 mg/L	7.3 mg/L
860430	0.07 mg/L	0.02 mg/L	0.04 mg/L	<0.01 mg/L	7.6 mg/L
860513	0.08 mg/L	0.03 mg/L	0.02 mg/L	<0.01 mg/L	6.7 mg/L
860521	0.08 mg/L	0.09 mg/L	0.02 mg/L	<0.01 mg/L	9.0 mg/L
860527	0.11 mg/L	0.08 mg/L	0.04 mg/L	<0.01 mg/L	7.9 mg/L
860603	0.05 mg/L	0.10 mg/L	0.04 mg/L	<0.01 mg/L	8.4 mg/L
860609	0.05 mg/L	0.06 mg/L	0.02 mg/L	<0.01 mg/L	9.7 mg/L
860624	0.09 mg/L	0.07 mg/L	0.04 mg/L	<0.01 mg/L	9.4 mg/L
AVERAGE	0.089	0.041	0.047	<0.01	8.5
MAXIMUM	0.20	0.10	0.15	<0.01	12.2
MINIMUM	0.50	0.003	<0.01	<0.01	5.4

WASTE MANAGEMENT PROGRAM

TABLE 8

Site Number: 0127620 Tsolum River at Farnham Road Bridge

Date	Aluminum total	Copper total	Iron total	Zinc total	Hardness total
850305	0.12 mg/L	<0.01 mg/L	0.28 mg/L	<0.01 mg/L	
850501	0.09 mg/L	0.006 mg/L	0.12 mg/L	<0.005 mg/L	9.8 mg/L
850530	0.14 mg/L	0.05 mg/L	0.10 mg/L	<0.005 mg/L	8.1 mg/L
850710	0.05 mg/L	0.004 mg/L	0.22 mg/L	0.007 mg/L	13.8 mg/L
850723	0.09 mg/L	0.004 mg/L	0.27 mg/L	0.02 mg/L	15.2 mg/L
850814	0.04 mg/L	0.005 mg/L	0.15 mg/L	<0.005 mg/L	14.9 mg/L
851003	0.02 mg/L	0.015 mg/L	0.08 mg/L	<0.01 mg/L	28.5 mg/L
851010	0.02 mg/L	0.02 mg/L	0.17 mg/L	<0.01 mg/L	11.4 mg/L
851021	2.32 mg/L	0.04 mg/L	3.55 mg/L	0.01 mg/L	13.2 mg/L
851031	0.07 mg/L	0.007 mg/L	0.11 mg/L	<0.01 mg/L	11.5 mg/L
851106	0.08 mg/L	0.007 mg/L	0.10 mg/L	<0.01 mg/L	12.0 mg/L
851112	0.06 mg/L	0.005 mg/L	0.12 mg/L	<0.01 mg/L	13.9 mg/L
860128	0.08 mg/L	0.013 mg/L	0.11 mg/L	<0.01 mg/L	9.0 mg/L
860225	0.37 mg/L	0.014 mg/L	0.53 mg/L	<0.01 mg/L	7.9 mg/L
860310	0.07 mg/L	0.003 mg/L	0.04 mg/L	<0.01 mg/L	9.2 mg/L
860416	0.12 mg/L	0.008 mg/L	0.19 mg/L	<0.01 mg/L	11.6 mg/L
860423	0.08 mg/L	0.011 mg/L	0.10 mg/L	<0.01 mg/L	10.4 mg/L
860430	0.14 mg/L	0.007 mg/L	0.07 mg/L	<0.01 mg/L	11.0 mg/L
860513	0.27 mg/L	0.10 mg/L	0.13 mg/L	<0.01 mg/L	10.2 mg/L
860521	0.09 mg/L	0.03 mg/L	0.12 mg/L	0.02 mg/L	11.4 mg/L
860527	0.21 mg/L	0.04 mg/L	0.23 mg/L	<0.01 mg/L	10.6 mg/L
860603	0.07 mg/L	0.03 mg/L	0.13 mg/L	<0.01 mg/L	10.7 mg/L
860609	0.07 mg/L	0.02 mg/L	0.19 mg/L	<0.01 mg/L	13.9 mg/L
860624	0.04 mg/L	0.012 mg/L	0.17 mg/L	<0.01 mg/L	11.9 mg/L
860707	0.03 mg/L	0.007 mg/L	0.16 mg/L	<0.01 mg/L	14.4 mg/L
860813	0.03 mg/L	0.005 mg/L	0.20 mg/L	<0.01 mg/L	
860915	0.05 mg/L	0.03 mg/L	0.07 mg/L	<0.01 mg/L	
AVERAGE	0.179	0.019	0.286	0.01	12.3
MAXIMUM	2.32	0.10	3.55	0.02	28.5
MINIMUM	0.02	0.003	0.04	<0.005	7.9

Date	Aluminum dissolved	Copper dissolved	Iron dissolved	Zinc dissolved	Hardness dissolved
851021	0.27 mg/L	0.02 mg/L	0.26 mg/L	<0.01 mg/L	9.3 mg/L
851031	0.03 mg/L	0.005 mg/L	0.07 mg/L	<0.01 mg/L	11.3 mg/L
851112	0.04 mg/L	0.004 mg/L	0.12 mg/L	<0.01 mg/L	13.7 mg/L
860128	0.07 mg/L	0.003 mg/L	<0.01 mg/L	<0.01 mg/L	8.6 mg/L
860225	0.09 mg/L	0.011 mg/L	0.09 mg/L	<0.01 mg/L	7.7 mg/L
860310	0.06 mg/L	0.003 mg/L	0.04 mg/L	<0.01 mg/L	9.2 mg/L
860416	0.05 mg/L	0.008 mg/L	0.05 mg/L	<0.01 mg/L	11.2 mg/L
860423	0.00 mg/L	0.011 mg/L	0.07 mg/L	<0.01 mg/L	10.4 mg/L
860430	0.05 mg/L	0.007 mg/L	0.07 mg/L	<0.01 mg/L	10.2 mg/L
860513	0.06 mg/L	0.040 mg/L	0.04 mg/L	<0.01 mg/L	10.2 mg/L
860521	0.06 mg/L	0.03 mg/L	0.06 mg/L	<0.01 mg/L	11.4 mg/L
860527	0.08 mg/L	0.03 mg/L	0.08 mg/L	<0.01 mg/L	10.5 mg/L
860603	0.03 mg/L	0.03 mg/L	0.09 mg/L	0.01 mg/L	10.3 mg/L
860609	0.05 mg/L	0.02 mg/L	0.06 mg/L	<0.01 mg/L	13.0 mg/L
860624	0.04 mg/L	0.012 mg/L	0.17 mg/L	<0.01 mg/L	11.9 mg/L
860627	0.03 mg/L	0.007 mg/L	0.13 mg/L	<0.01 mg/L	14.4 mg/L
AVERAGE	0.069	0.016	0.088	0.01	10.8
MAXIMUM	0.27	0.040	0.26	0.01	14.4
MINIMUM	0.03	0.003	<0.01	<0.01	7.7

WASTE MANAGEMENT PROGRAM

TABLE 9

Site Number: 0127621 Tsolum River U/S Puntledge River

Date	Aluminum Total	Copper Total	Iron Total	Zinc Total	Hardness Total
850305	0.33 mg/L	<0.01 mg/L	0.55 mg/L	<0.01 mg/L	
851021	1.94 mg/L	0.03 mg/L	2.61 mg/L	0.02 mg/L	
851031	0.08 mg/L	0.003 mg/L	0.13 mg/L	<0.01 mg/L	
851106	0.07 mg/L	<0.001 mg/L	0.18 mg/L	<0.01 mg/L	
851112	0.07 mg/L	0.004 mg/L	0.12 mg/L	<0.01 mg/L	
861126	0.09 mg/L	0.020 mg/L	0.17 mg/L	<0.01 mg/L	
860128	0.13 mg/L	0.003 mg/L	0.16 mg/L	<0.01 mg/L	
860225	1.52 mg/L	0.013 mg/L	2.00 mg/L	<0.01 mg/L	
860310	0.17 mg/L	0.001 mg/L	0.16 mg/L	<0.01 mg/L	
860416	0.17 mg/L	0.006 mg/L	0.30 mg/L	0.03 mg/L	
860423	0.06 mg/L	0.008 mg/L	0.11 mg/L	<0.01 mg/L	
860430	0.08 mg/L	0.005 mg/L	0.16 mg/L	<0.01 mg/L	
860513	<0.02 mg/L	0.004 mg/L	0.11 mg/L	<0.01 mg/L	
860521	0.11 mg/L	0.03 mg/L	0.18 mg/L	<0.01 mg/L	
860527	0.29 mg/L	0.03 mg/L	0.28 mg/L	<0.01 mg/L	
860603	0.05 mg/L	0.02 mg/L	0.14 mg/L	<0.01 mg/L	
860609	0.07 mg/L	0.012 mg/L	0.14 mg/L	<0.01 mg/L	
AVERAGE	0.308	0.441	0.012	0.012	
MAXIMUM	1.940	2.610	0.030	0.030	
MINIMUM	0.020	0.220	0.001	0.010	

Date	Aluminum Dissolved	Copper Dissolved	Iron Dissolved	Zinc Dissolved	Hardness Dissolved
851021	0.22 mg/L	0.011 mg/L	0.29 mg/L	<0.01 mg/L	
851031	<0.02 mg/L	0.003 mg/L	0.04 mg/L	<0.01 mg/L	
851112	0.07 mg/L	0.004 mg/L	0.10 mg/L	<0.01 mg/L	
861126	0.06 mg/L	0.02 mg/L	0.11	<0.01 mg/L	
860128	0.06 mg/L	0.003 mg/L	0.07 mg/L	<0.01 mg/L	
860225	0.14 mg/L	0.007 mg/L	0.17 mg/L	<0.01 mg/L	
860310		0.001 mg/L		<0.01 mg/L	
860416	0.05 mg/L	0.006 mg/L	0.07 mg/L	<0.01 mg/L	
860423	0.05 mg/L	0.008 mg/L	0.10 mg/L	<0.01 mg/L	
860430	0.04 mg/L	0.005 mg/L	0.08 mg/L	<0.01 mg/L	
860513	0.04 mg/L		0.06 mg/L	<0.01 mg/L	
860521	0.04 mg/L	0.02 mg/L	0.06 mg/L	<0.01 mg/L	
860527	0.06 mg/L	0.02 mg/L	0.07 mg/L	<0.01 mg/L	
860603	0.05 mg/L	0.017 mg/L	0.08 mg/L	<0.01 mg/L	
860609	0.03 mg/L	0.012 mg/L	0.06 mg/L	<0.01 mg/L	
AVERAGE	0.066	0.010	0.097	0.010	
MAXIMUM	0.220	0.020	0.290	0.010	
MINIMUM	0.020	0.001	0.040	0.010	

WASTE MANAGEMENT PROGRAM

TABLE 10

Site Number: E206513 Tsolum River at Duncan Bay Main Road

Date	Aluminum total	Copper total	Iron total	Zinc total	Hardness total
851021	1.73 mg/L	0.003 mg/L	2.52 mg/L	0.01 mg/L	14.6 mg/L
851031	0.08 mg/L	0.02 mg/L	0.05 mg/L	<0.01 mg/L	9.0 mg/L
851106	0.08 mg/L	0.001 mg/L	0.18 mg/L	<0.01 mg/L	13.8 mg/L
851112	0.06 mg/L	0.003 mg/L	0.19 mg/L	<0.01 mg/L	14.7 mg/L
850126	0.06 mg/L	0.003 mg/L	0.25 mg/L	<0.01 mg/L	22.7 mg/L
860128	0.06 mg/L	<0.001 mg/L	0.09 mg/L	<0.01 mg/L	9.3 mg/L
860225	0.19 mg/L	0.002 mg/L	0.26 mg/L	<0.01 mg/L	8.6 mg/L
860310	0.16 mg/L	0.002 mg/L	0.15 mg/L	<0.01 mg/L	10.0 mg/L
860416	0.07 mg/L	<0.001 mg/L	0.17 mg/L	<0.01 mg/L	13.4 mg/L
860423	0.03 mg/L	0.003 mg/L	0.24 mg/L	<0.01 mg/L	11.6 mg/L
860430	0.08 mg/L	0.002 mg/L	0.16 mg/L	<0.01 mg/L	11.3 mg/L
860513	0.02 mg/L	0.002 mg/L	0.14 mg/L	<0.01 mg/L	12.5 mg/L
860521	0.06 mg/L	0.002 mg/L	0.32 mg/L	<0.01 mg/L	14.9 mg/L
860527	0.08 mg/L	0.001 mg/L	0.29 mg/L	<0.01 mg/L	12.9 mg/L
860603	0.03 mg/L	0.003 mg/L	0.44 mg/L	<0.01 mg/L	16.1 mg/L
860609	0.06 mg/L	0.003 mg/L	0.82 mg/L	<0.01 mg/L	20.7 mg/L
860624	0.03 mg/L	0.002 mg/L	0.61 mg/L	<0.01 mg/L	15.7 mg/L
860707	0.04 mg/L	0.001 mg/L	0.70 mg/L	<0.01 mg/L	20.4 mg/L
860813	0.02 mg/L	0.02 mg/L	0.89 mg/L	<0.01 mg/L	23.8 mg/L
860915	0.02 mg/L	0.001 mg/L	0.84 mg/L	<0.01 mg/L	28.8 mg/L
AVERAGE	0.147	0.004	0.465	0.01	15.2
MAXIMUM	1.73	0.02	2.52	0.01	28.8
MINIMUM	0.02	<0.001	0.05	0.01	8.6

Date	Aluminum dissolved	Copper dissolved	Iron dissolved	Zinc dissolved	Hardness dissolved
851021	0.13 mg/L	<0.001 mg/L	0.17 mg/L	<0.01 mg/L	10.3 mg/L
851031	0.05 mg/L	0.02 mg/L	0.04 mg/L	<0.01 mg/L	8.9 mg/L
851106	0.08 mg/L	0.001 mg/L	0.17 mg/L	<0.01 mg/L	13.8 mg/L
851112	0.06 mg/L	0.002 mg/L	0.15 mg/L	<0.01 mg/L	14.7 mg/L
860126	0.02 mg/L	<0.001 mg/L	0.16 mg/L	<0.01 mg/L	16.5 mg/L
860128	0.05 mg/L	<0.001 mg/L	0.06 mg/L	<0.01 mg/L	8.2 mg/L
860225	0.12 mg/L	0.002 mg/L	0.10 mg/L	<0.01 mg/L	7.1 mg/L
860310	0.14 mg/L	0.001 mg/L	0.15 mg/L	<0.01 mg/L	9.7 mg/L
860416	0.05 mg/L	<0.001 mg/L	0.12 mg/L	<0.01 mg/L	12.3 mg/L
860423	0.03 mg/L	0.003 mg/L	0.10 mg/L	<0.01 mg/L	11.1 mg/L
860430	0.08 mg/L	0.002 mg/L	0.16 mg/L	<0.01 mg/L	11.1 mg/L
860513	<0.02 mg/L	0.002 mg/L	0.10 mg/L	<0.01 mg/L	12.5 mg/L
860521	0.03 mg/L	0.001 mg/L	0.16 mg/L	<0.01 mg/L	14.9 mg/L
860527	0.04 mg/L		0.14 mg/L	<0.01 mg/L	12.8 mg/L
860603	<0.02 mg/L	0.002 mg/L	0.23 mg/L	<0.01 mg/L	16.0 mg/L
860609	0.02 mg/L	0.002 mg/L	0.37 mg/L	<0.01 mg/L	19.6 mg/L
AVERAGE	0.06	0.003	0.15	<0.01	12.5
MAXIMUM	0.14	0.02	0.37	<0.01	19.6
MINIMUM	<0.02	<0.001	0.04	<0.01	7.1

WASTE MANAGEMENT PROGRAM

TABLE 11

Site Number: E206514 One-Twenty-six Creek at Ski Shack

Date	Aluminum total	Copper total	Iron total	Zinc total
851023	0.34 mg/L	0.13 mg/L	0.13 mg/L	0.02 mg/L
851031	0.26 mg/L	0.10 mg/L	0.13 mg/L	<0.01 mg/L
851106	0.34 mg/L	0.14 mg/L	0.08 mg/L	0.02 mg/L
851112	0.28 mg/L	0.11 mg/L	0.17 mg/L	<0.01 mg/L
860416	0.13 mg/L	0.10 mg/L	0.09 mg/L	0.01 mg/L
860423	0.27 mg/L	0.14 mg/L	0.01 mg/L	<0.01 mg/L
860430	0.42 mg/L	0.14 mg/L	0.11 mg/L	<0.01 mg/L
860513	0.37 mg/L	0.13 mg/L	0.10 mg/L	0.01 mg/L
860521	0.40 mg/L	0.11 mg/L	0.11 mg/L	0.01 mg/L
860527	0.58 mg/L	0.22 mg/L	0.16 mg/L	0.02 mg/L
860603	0.51 mg/L	0.30 mg/L	0.10 mg/L	0.03 mg/L
860609	0.61 mg/L	0.40 mg/L	0.18 mg/L	0.02 mg/L
860624	0.51 mg/L	0.28 mg/L	0.12 mg/L	0.02 mg/L
AVERAGE	0.386	0.177	0.115	0.015
MAXIMUM	0.610	0.400	0.180	0.030
MINIMUM	0.130	0.100	0.010	0.010

Date	Aluminum dissolved	Copper dissolved	Iron dissolved	Zinc dissolved
851023	0.29 mg/L	0.12 mg/L	<0.01 mg/L	<0.01 mg/L
851112	0.12 mg/L	0.11 mg/L	0.09 mg/L	<0.01 mg/L
860423	0.27 mg/L	0.14 mg/L	<0.01 mg/L	0.03 mg/L
860430	0.14 mg/L	0.11 mg/L	0.11 mg/L	0.03 mg/L
860513	0.25 mg/L	0.13 mg/L	0.10 mg/L	<0.01 mg/L
860521	0.29 mg/L	0.10 mg/L	0.08 mg/L	0.01 mg/L
860527	0.46 mg/L	0.22 mg/L	0.08 mg/L	<0.01 mg/L
860603	0.45 mg/L	0.29 mg/L	0.08 mg/L	0.02 mg/L
860609	0.46 mg/L	0.39 mg/L	0.05 mg/L	0.02 mg/L
AVERAGE	0.303	0.179	0.068	0.017
MAXIMUM	0.46	0.39	0.11	0.03
MINIMUM	0.12	0.10	0.01	0.01

WASTE MANAGEMENT PROGRAM

TABLE 12

Site Number: 0125901 Pyrrhotite Creek at Branch 126

Date	pH	Specific Conductance	Calcium	Sulphate dissolved	Alkalinity total 4.5
850530		140 uS/cm	5.40 mg/L	41.5 mg/L	
850723	3.9 pH units	274 uS/cm	23.90 mg/L	53.5 mg/L	<0.5 mg/L
851003		500 uS/cm	46.70 mg/L	236.0 mg/L	
851010	4.1 pH units	333 uS/cm	25.80 mg/L	None	<0.5 mg/L
851023	3.8 pH units	445 uS/cm	32.60 mg/L	198.0 mg/L	
851031	4.2 pH units	415 uS/cm	29.80 mg/L	186.0 mg/L	<0.5 mg/L
851106	3.9 pH units	403 uS/cm	33.90 mg/L	184.0 mg/L	<0.5 mg/L
851112	3.9 pH units	418 uS/cm	34.70 mg/L	101.0 mg/L	<0.5 mg/L
851126	4.2 pH units	400 uS/cm	34.70 mg/L	181.0 mg/L	<0.5 mg/L
860206		335 uS/cm	23.90 mg/L	150.0 mg/L	
860403	4.1 pH units	274 uS/cm	22.70 mg/L	121.0 mg/L	<0.5 mg/L
860416	4.1 pH units	308 uS/cm	23.60 mg/L	130.0 mg/L	<0.5 mg/L
860422	3.8 pH units	343 uS/cm	25.20 mg/L	154.0 mg/L	<0.5 mg/L
860423	3.8 pH units	343 uS/cm	26.00 mg/L	148.0 mg/L	<0.5 mg/L
860430	4.1 pH units	330 uS/cm	24.80 mg/L	143.0 mg/L	<0.5 mg/L
860507	4.0 pH units	255 uS/cm	21.10 mg/L	115.0 mg/L	<0.5 mg/L
860513	3.9 pH units	281 uS/cm	21.20 mg/L	125.0 mg/L	<0.5 mg/L
860521	3.7 pH units	270 uS/cm	15.90 mg/L	109.0 mg/L	<0.5 mg/L
860527	3.8 pH units	209 uS/cm	10.90 mg/L	79.0 mg/L	<0.5 mg/L
860603	3.9 pH units	121 uS/cm	5.23 mg/L	37.5 mg/L	<0.5 mg/L
860609	3.9 pH units	130 uS/cm	6.08 mg/L	42.7 mg/L	<0.5 mg/L
860624	3.7 pH units	255 uS/cm	13.90 mg/L	98.4 mg/L	<0.5 mg/L
860707	3.8 pH units	280 uS/cm	20.50 mg/L	122.0 mg/L	<0.5 mg/L
860813	4.0 pH units	417 uS/cm	39.30 mg/L	190.0 mg/L	<0.5 mg/L
860915	4.1 pH units	470 uS/cm	48.00 mg/L	216.0 mg/L	<0.5 mg/L
AVERAGE	3.9	317	24.7	135.5	0.5
MAXIMUM	4.2	500	48.	236.0	0.5
MINIMUM	3.7	121	5.23	37.5	0.5

WASTE MANAGEMENT PROGRAM

TABLE 13

Site Number: E206501 Pyrrhotite Creek at Rossiter Main Road

Date	pH	Specific Conductance	Calcium	Sulphate dissolved	Alkalinity total 4.5
851031			2.42 mg/L		
851106			2.82 mg/L		
851112			3.48 mg/L		
851126			3.68 mg/L		
860128			1.69 mg/L		
860225	6.8 pH units	16 uS/cm	1.80 mg/L	3.5 mg/L	
860310	6.7 pH units	14 uS/cm	1.85 mg/L	2.7 mg/L	
860416	7.0 pH units	17 uS/cm	2.18 mg/L	2.2 mg/L	
860423	6.9 pH units	22 uS/cm	2.40 mg/L	4.7 mg/L	
860430	6.5 pH units	15 uS/cm	1.94 mg/L	2.5 mg/L	
860513			2.57 mg/L		
860521	5.8 pH units	35 uS/cm	3.38 mg/L	11.6 mg/L	
860527	6.7 pH units	21 uS/cm	3.37 mg/L	4.9 mg/L	
860603	5.6 pH units	45 uS/cm	4.03 mg/L	15.2 mg/L	
860609	6.2 pH units	42 uS/cm	4.31 mg/L	13.6 mg/L	
860624	6.6 pH units	23 uS/cm	2.85 mg/L	5.5 mg/L	6.7 mg/L
860707			3.91 mg/L		
860813	7.0 pH units	47 uS/cm	5.84 mg/L		
860915			5.38 mg/L		
AVERAGE	6.5	27	3.15	6.64	6.7
MAXIMUM	7.0	47	5.84	15.20	6.7
MINIMUM	5.6	14	1.69	2.20	6.7

WASTE MANAGEMENT PROGRAM

TABLE 14

Site Number: E206499 Murex Creek at Duncan Main Road

Date	pH	Specific Conductance	Calcium	Sulphate dissolved	Alkalinity total 4.5
85102	6.8 pH units	19 uS/cm	2.73 mg/L		
85103			3.09 mg/L		
85110			2.99 mg/L		
85112			3.63 mg/L		
86012			1.84 mg/L		
86022	6.6 pH units	16 uS/cm	1.88 mg/L	3.4 mg/L	
86031	6.9 pH units	16 uS/cm	2.03 mg/L	2.8 mg/L	
86041	7.4 pH units	20 uS/cm	2.65 mg/L	3.2 mg/L	
86042	6.9 pH units	20 uS/cm	2.35 mg/L	3.7 mg/L	
86043	6.5 pH units	18 uS/cm	2.25 mg/L	3.0 mg/L	
86051	7.0 pH units	18 uS/cm	2.23 mg/L	3.0 mg/L	
86052	6.7 pH units	22 uS/cm	2.75 mg/L	6.1 mg/L	
86052	6.8 pH units	19 uS/cm	2.48 mg/L	4.3 mg/L	
86060	7.0 pH units	22 uS/cm	2.57 mg/L	6.3 mg/L	4.8 mg/L
86060	6.8 pH units	23 uS/cm	3.00 mg/L	5.8 mg/L	
86062	6.7 pH units	22 uS/cm	2.79 mg/L	4.7 mg/L	6.9 mg/L
86070			3.27 mg/L		
86081	7.2 pH units	41 uS/cm	4.51 mg/L		
AVERAGE	6.9	21	2.72	4.3	5.8
MAXIMUM	7.4	41	4.51	6.3	6.9
MINIMUM	6.5	16	1.84	2.8	4.8

WASTE MANAGEMENT PROGRAM

TABLE 15

Site Number: 0127620 Tsolum River at Farnham Road Bridge

Date	pH	Specific Conductance	Calcium	Sulphate dissolved	Alkalinity total 4.5
850305	7.2 pH units	27 uS/cm	2.41 mg/L	1.3 mg/L	12.1 mg/L
850501	6.9 pH units	22 uS/cm	2.79 mg/L	1.8 mg/L	9.8 mg/L
850530			2.38 mg/L		
850710	7.2 pH units	41 uS/cm	4.05 mg/L	3.7 mg/L	14.4 mg/L
850723			4.54 mg/L		
850814			4.34 mg/L		
851003			5.30 mg/L		
851010			3.80 mg/L		
851021	6.6 pH units	22 uS/cm	3.25 mg/L		
851031			3.15 mg/L		
851106			3.51 mg/L		
851112			4.10 mg/L		
860128	7.3 pH units	23 uS/cm	2.52 mg/L	2.0 mg/L	
860225	6.7 pH units	20 uS/cm	2.16 mg/L	2.4 mg/L	
860310	6.9 pH units	22 uS/cm	2.66 mg/L	2.1 mg/L	
860416	7.5 pH units	28 uS/cm	2.84 mg/L	2.3 mg/L	
860423	6.9 pH units	27 uS/cm	2.96 mg/L	2.5 mg/L	
860430	6.7 pH units	26 uS/cm	3.10 mg/L	1.9 mg/L	
860513	7.3 pH units	24 uS/cm	2.88 mg/L	2.7 mg/L	
860521	6.7 pH units	26 uS/cm	3.30 mg/L	4.6 mg/L	
860527	7.0 pH units	24 uS/cm	3.11 mg/L	2.9 mg/L	
860603	7.6 pH units	26 uS/cm	3.09 mg/L	4.1 mg/L	
860609	7.0 pH units	28 uS/cm	3.72 mg/L	3.8 mg/L	
860624	6.9 pH units	20 uS/cm	3.42 mg/L	3.2 mg/L	11.6 mg/L
860707	7.2 pH units	35 uS/cm	4.10 mg/L	3.0 mg/L	
860813	7.2 pH units	42 uS/cm	4.46 mg/L	2.8 mg/L	
860915	7.2 pH units	45 uS/cm	4.33 mg/L	2.8 mg/L	
AVERAGE	7.1	28	3.42	2.8	12.0
MAXIMUM	7.6	45	5.3	4.6	14.4
MINIMUM	6.6	20	2.16	1.3	9.8

WASTE MANAGEMENT PROGRAM

TABLE 16

Site Number: 0127621 Tsolum River U/S Puntledge River

Date	pH	Specific Conductance	Calcium	Sulphate dissolved	Alkalinity total 4.5
850305	7.3 pH units	42 uS/cm	3.31 mg/L	1.9 mg/L	1.50 mg/L
851021	7.0 pH units	33 uS/cm	4.04 mg/L		
851031			4.78 mg/L		
851106			4.39 mg/L		
851112			5.28 mg/L		
850126			5.64 mg/L		
860128			3.08 mg/L		
860225			3.07 mg/L		
860310			3.44 mg/L		
860416			3.61 mg/L		
860423			3.34 mg/L		
860430			3.52 mg/L		
860513			3.41 mg/L		
860521			3.80 mg/L		
860527			3.42 mg/L		
860603			3.74 mg/L		
860609			4.34 mg/L		
860624			3.80 mg/L		
860707			3.62 mg/L		
860915			6.27 mg/L		
AVERAGE	7.1	37	4.04	1.9	1.50
MAXIMUM	7.3	42	6.27	1.9	1.50
MINIMUM	7.0	33	3.07	1.9	1.50

WASTE MANAGEMENT PROGRAM

TABLE 17

Site Number: E206513 Tsolum River at Duncan Main Road

Date	pH	Specific Conductance	Calcium	Sulphate dissolved	Alkalinity total 4.5
851021	6.9 pH units	21 uS/cm	3.61 mg/L		
851031			2.57 mg/L		
851106			3.79 mg/L		
851112			4.05 mg/L		
850126			6.74 mg/L		
860128			2.42 mg/L		
860225			2.29 mg/L		
860310			2.58 mg/L		
860416			3.16 mg/L		
860423			3.03 mg/L		
860430			2.90 mg/L		
860513			3.30 mg/L		
860521			3.97 mg/L		
860527			3.49 mg/L		
860603			4.25 mg/L		
860609			5.55 mg/L		
860624	6.8 pH units	39 uS/cm	4.14 mg/L	2.0 mg/L	17.5 mg/L
860707			5.54 mg/L		
860813			6.43 mg/L		
860915			8.00 mg/L		
AVERAGE	6.8	30	4.09	2.0	17.5
MAXIMUM	6.9	39	8.00	2.0	17.5
MINIMUM	6.8	21	2.29	2.0	17.5

WASTE MANAGEMENT PROGRAM

TABLE 18

Site Number: E206514 One-Twenty-six Creek at Ski Shack

Date	pH	Specific Conductance	Calcium	Sulphate dissolved	Alkalinity total 4.5
851023	5.5 pH units	38 uS/cm	3.87 mg/L		
851031			4.11 mg/L		
851106	5.6 pH units	42 uS/cm	4.62 mg/L		
851112	6.0 pH units	43 uS/cm	5.33 mg/L		
860416	6.2 pH units		3.46 mg/L		
860423			3.10 mg/L		
860430			3.73 mg/L		
860513			2.62 mg/L		
860521			2.57 mg/L		
860527			2.24 mg/L		
860603			2.04 mg/L		
860609			2.95 mg/L		
860624			3.19 mg/L		
AVERAGE	5.8	41	3.38		
MAXIMUM	6.2	43	5.33		
MINIMUM	5.5	38	2.04		

TABLE 19

1984 & 1985 PUNTLEDGE HATCHERY WATER SAMPLING PROGRAM RESULTS
FOR EXTRACTABLE COPPER [mg/L]

Date - 1984	Murex Ck at Duncan Bay Main Road	Mid Tsolum R at Headquarters Creek
January 4		<.005
March 7	.015	.006
April 11	.013	.006
May 23	.029	.013
June 13	.089	.064
July 12	.067	.036
August 21	.018	.009
September 12	.034	.011
October 16	.032	.011
November 6	.028	.014
December 19	.013	<.005

Date - 1985	Murex Ck at Duncan Bay Main Road	Mid Tsolum R at Headquarters Creek
January 15	.011	<.005
February 12		<.005
March 13	.005	<.005
April 10	.019	.007
May 15	.027	.017
May 16	.039	
May 22	.115	
May 24	.122	
May 27	.094	
May 31	.098	
June 3	.092	
June 6	.066	.032
June 11	.066	
June 12	.083	.027
June 17	.050	
June 18	.050	
June 19	.046	
June 20	.038	
June 21	.036	
June 26	.019	
June 28	.018	.008
July 2	.013	
July 4	.014	
July 5	.013	
July 8	.010	
July 10	.011	.006
July 15	.012	
July 22	.014	
August 20	.007	.009
October 9	<.005	<.005
October 22	.035	.018
December 9	.017	.006
December 16	<.005	<.005

TABLE 20

1986 PUNTLEDGE HATCHERY WATER SAMPLING PROGRAM RESULTS
FOR EXTRACTABLE COPPER [mg/L]

Date	Pyrrhotite Creek at Rossiter Mainline	Murex Creek at Duncan Bay Main Road	Mid Tsolum River at Headquarters Creek	Lower Tsolum River at Dove Creek Road	Courtenay River
Jan. 13	.043	.016	.006		
20	.044	.019	.008		
27	.032	.013	<.005		
Feb. 3	.044	.020	.006		
10	.043	.013	<.005	<.005	
17	.038	.010	<.005		
24	.069	.019	.012		
Mar. 3	.073	.020	.007		
10	.088	.028	.010		
17	.052	.017	.005		
24	.054	.022	.007	.005	<.005
31	.058	.021	.007		
Apr. 7	.067	.021	.007		
14	.082	.026	.008		
21	.061	.036	.011	.007	<.005
28	.062	.024	.017		
May 2	.106	.038	.014		.001
5	.171	.029	.010		
9	.132	.035	.013		<.005
12	.148	.037	.012		
20	.699	.031	.041	.010	<.005
23	.365	.076	.032		<.005
26	.388	.126	.069		
27	.337	.104			
30	.693		.055		<.005
June 2	1.001	.128	.045		
9	.77	.058	.025		
13	.959	.052	.022		<.005
16	.207	.083	.073	.058	.010
20	.191	.051	.030		<.005
23	.225	.027	.021		
30	.146	.030	.010		
July 7	.369	.049	.007		